Mariners Weather Log

Fall 1993

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Wave Special!

4
Simply Awesome
Michael Rogers

8
Shiphandling in Heavy Seas
Captain Jeffrey W. Monroe

14
Freak Waves!
Jerome W. Nickerson

20
Solitary Waves
Lieutenant Commander Robert Irving, USN (Retired)

24
High Waves in the Aghulhas Current
F.A. Shillington and E.H. Schumann

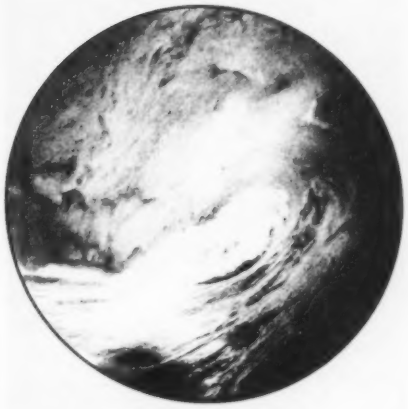
29
A Tsunami is Coming!
Michael J. Mooney

33
Buoy Wave Extremes
David B. Gilhousen

Cover: Warren Bolster's wave photographs can be found throughout this issue. The one on the cover was shot in Hawaii and is typical of the waves that can affect these islands and the West Coast of the United States.

Inside Front Cover: Wolf Rock Lighthouse some 8 miles southwest of Lands End on the southern coast of England is the site of some spectacular wave action and its story can be found on page 38.

Back Cover: Michael Halminski contributes a wave photograph from along the East Coast of the United States, where northeasters and tropical cyclones are the main producers of big surf. This was shot after the Halloween Storm of 1991.



Departments

35 Editor's Choice

38 Whale Oil and Wicks

41 Great Lakes Wrecks

42 Mailbag

44 Lifelines

48 Ocean Queries

51 Satellite Snapshots

52 Sea Photography

54 Hurricane Alley

59 PMO Report

66 Marine Observation Program

Marine Weather Review

April, May, and June1993

70 North Atlantic Weather

73 North Pacific Weather

77 Pressure and Track Charts

86 Tables

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Editor
Richard M. DeAngelis

Associate Editor
Nancy O'Donnell

Columnists
Elinor DeWire
Marty Baron
Michael Halminski
Skip Gillham

Computer Specialists
Gary Keull
Wilbur Biggs
Dick Knight

Satellite Coordinator
Jenifer Clark

U.S. Department of Commerce
Ronald H. Brown, Secretary

National Oceanic and Atmospheric Administration
Dr. D. James Baker
Administrator

National Environmental Satellite, Data, and Information Service
Robert S. Winokur, Assistant Administrator

National Weather Service
Elbert W. Friday Jr., Assistant Administrator

National Oceanographic Data Center
Bruce C. Douglas, Director

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Editor, Mariners Weather Log
National Oceanographic Data Center
1825 Conn. Av., NW
Washington DC 20235.

About this issue

Every once in awhile we try to do a theme issue since these are very popular and often requested. That issue usually becomes known by the theme. We frequently get requests for the *hurricane issue* or the *gold issue*. Sometimes the cover makes enough of an impression that someone will write in and ask for, say, the *blimp issue*. This time we have a cover and theme that we believe is universal in appeal and most important to those who make their living at sea. We hope this becomes known as the *wave issue*.

These theme issues are tough to put together and take the cooperation of our regular columnists and a great deal of other helpful people who go out of their way for us. While we may miss a few it is important to recognize these efforts. Warren Bolster, for example, provided many of the great surf shots throughout the magazine. It was thanks to Lilian Ong of the Hawaii Visitors Bureau who tipped us off to Warren. Warren is a professional photographer and a great guy. Phil Roberts donated his wonderful artwork to help illustrate *Simply Awesome*, an article that captures both the beauty and danger of waves. We are grateful to both the author--Michael Rogers--and the National Wildlife Federation. Thanks to Dr. Nan Walker at L.S.U., who was traveling to South Africa and volunteered to talk to her old friend Eckhart Schumann, who co-authored with Frank Shillington an excellent updated article on the dangerous waves in the Agulhas Curren. Jerry Nickerson, former head of the VOS program, was most encouraging about this issue and contributed an important piece on Freak Waves-- his favorite topic throughout the years. Note how the piece by Captain Cameron from the *Marine Observer*, found in the Editor's Choice column, fits right in with Nickerson's article.

We would like to draw your attention to the piece in Hurricane Alley. ***President Madison** and the Christmas Day Typhoon* is a masterpiece of storytelling. This article was first brought to our attention by Jack Henry, brother-in-law of author Archie McLaren, and an offficer in the Puget Sound Maritime Historical Society. Scotty Broom of George Broom & Sons Sailmaker in Seattle was kind enough to loan us the photograph.

Jeff Monroe's article evolved from a visit that Vince Zegowitz and I made to the Massachusetts Maritime Academy last winter. We had always wanted to publish a comprehensive article on shiphandling in rough seas but had no luck in tracking one down until Jeff volunteered. We ran across Robert Irving's solitary wave piece in an old *MTS Journal* and thought it would be a good addition to the Log. Both Bob and the Marine Technology Society were most cooperative. The search for photographs to illustrate this article took us to Alaska and a most helpful archivist-- M. Dianne Brenner at the Anchorage Museum of History and Art. She had some good suggestions on tidal bore photos as well as some other source information.

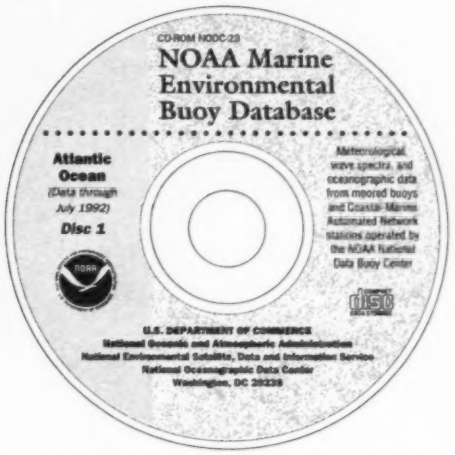
Michael Mooney-- widely published and a well respected science writer is always there with a well-written, interesting article with good illustrations. Well along into this issue, we felt that we should include something by the National Data Buoy Center since they are a collecter of wave data. One phone call and Dave Gilhousen not only offered to write something, but on an important subject which has not received its due-- wave steepness.

In the query column what more appropriate question than how high can waves get? This query has been posed quite often and we thought that Dr. Joseph Goldman provided a rational, easy-to-understand discussion of a highly technical question in an interview that appeared in *Ocean Industry*.

Whenever we are in a bind for some good photographs of maritime paintings we can always count on the Mariner's Museum in Newport News, VA. They seem to have an inexhaustible supply and they are very helpful, as was the Metropolitan Museum of Art in New York where we tracked down the Tsunami woodblock print. As usual Michael Halminski, Elinor De Wire, Skip Gillham, and Marty Baron came through with columns that reflect the main theme of this issue-- dangerous waves.

Now on CD-ROM

NOAA Marine Environmental Buoy Database


CD-ROM NODC-23
NOAA Marine Environmental Buoy Database
Atlantic Ocean
(Data through July 1992)
Disc 1
Meteorological, wave spectra, and oceanographic data from moored buoys and Coastal-Marine Automated Network stations operated by the NOAA National Data Buoy Center
U.S. DEPARTMENT OF COMMERCE
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National Oceanographic Data Center
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7.9 gigabytes of ocean wind/wave data on 14 discs

Wind, wave, and other marine data collected by the NOAA National Data Buoy Center (NDBC) are now available for the first time on CD-ROM.

The database

The NOAA Marine Environmental Buoy Database holds data from NDBC moored buoys and from C-MAN (Coastal-Marine Automated Network) stations located on piers, offshore towers, lighthouses, and beaches. Parameters reported by both buoys and C-MAN stations include air temperature and pressure, wind speed and direction, wind gust, and sea surface temperature. The buoys—and a few C-MAN stations located on offshore towers—also report wave data, usually including wave height, wave period, and wave spectra. Since the late 1980s some buoys have reported directional wave spectra.

The CD-ROMs

This set of 14 CD-ROMs holds all data from the National Oceanographic Data Center archive of NOAA buoy and C-MAN station data though July 1992. The earliest buoy data are from October 1972, and the earliest C-MAN data are from January 1985. The data are organized by ocean area, and files for each moored buoy or C-MAN station are arranged in directories by their station identifier. Each file contains one month of data. The data and documentation files are in ASCII format. Update discs holding data from August 1992 onward will be issued in the future. Data selected from the NOAA Marine Environmental Buoy Database—including the more recent data—can also be provided to NODC customers on other media.

How to order

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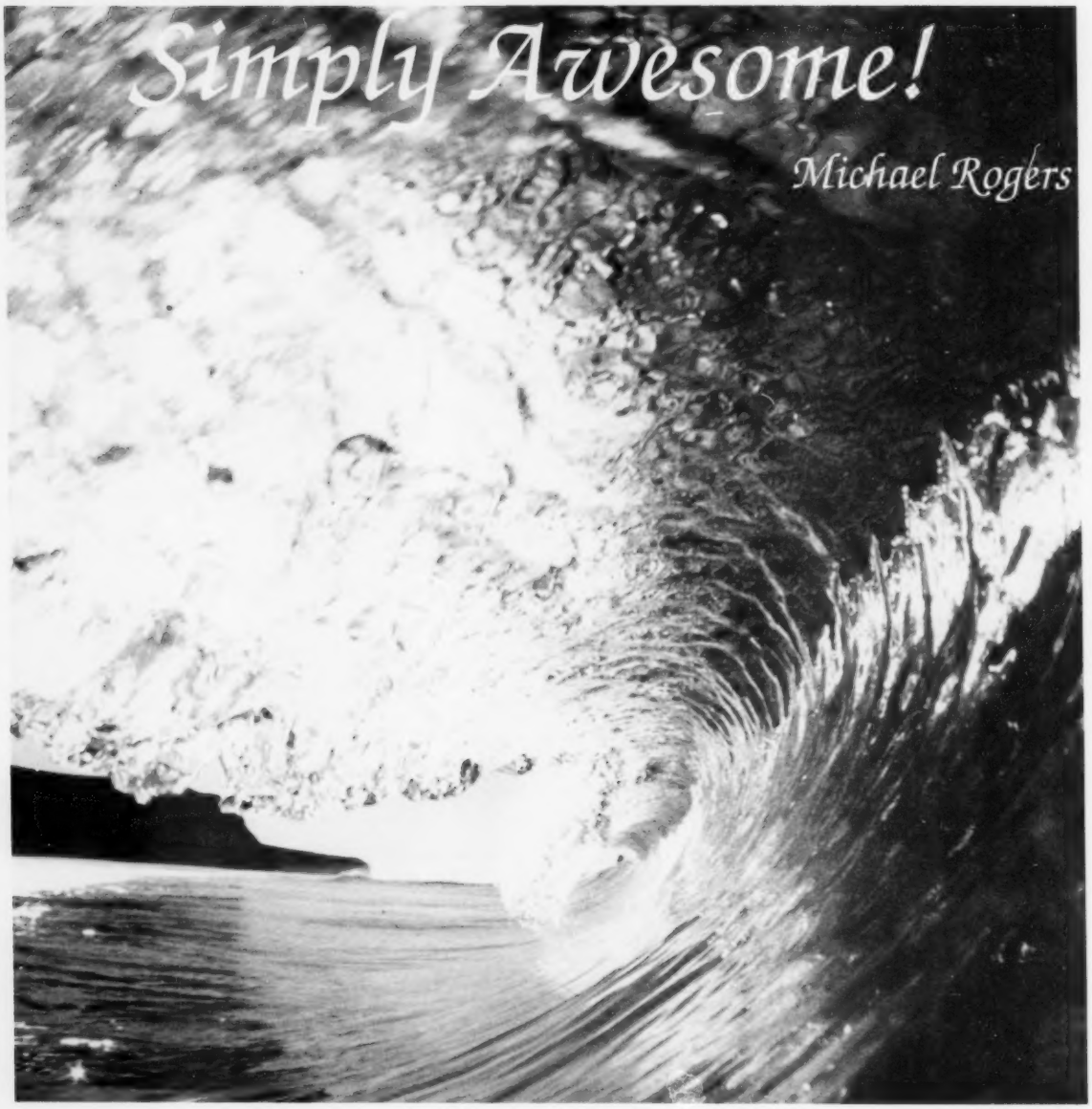
Simply Awesome!

Michael Rogers



Warren Bolster

Clustered together in a bright concrete gallery at the Monterey Bay Aquarium in California, a dozen kids stare at the glass front of a wide tank. The attraction is unclear: the display contains a rocky undersea bluff with droopy sea palms, various algae, a few starfish, anemones, sea urchins, all hanging on, immobile, with water dripping slowly into a small tidepool at the tank's bottom. It seems a drab and static vision to so enthrall the kids, but then suddenly comes the twist they're awaiting. An immense gush of sea water— about 200 gallons, nearly a ton in weight—falls from the upper right of the tank and explodes in foam and spray. The kids scream, giggle, fall back. The sea palms and companions stolidly withstand the automated onslaught they endure every 45 seconds, around the clock.

For these tidal denizens it's just another day's work. And for the kids, now awaiting another crash of water, it's a high–tech version of one of our species' oldest relaxations: watching waves.

Hawaii Maritime Center

This is the tsunami that devastated Hilo, HI on April 1, 1946, photograph courtesy of the Hawaii Maritime Center.

Waves definitely deserve their quota of contemplation. They represent a continual dance between ocean and air, fueled by sun and wind, shaped by the sea floor, capable of inducing soothing meditation or a cataclysm akin to a small nuclear weapon. Waves can banish a beach overnight, then build a new one the next spring. Waves feed, shelter, and transport a myriad of life-forms, often nourishing a rock-bound filter feeder, then moments later knocking it into the maw of a hungry predator lurking below. Yet in the end, perhaps the most romantic and ineluctable aspect of waves is the perennial fascination they present for humans.

Most have at some point followed John Keats' two-century old prescription for world-weary eyes: "Feast them upon the wideness of the Sea...." The view is rich and endlessly varied in form, from the wind-blown scatter pattern known technically as "sea" to the immense tsunamis that can wipe entire towns off the Earth. The mathematics of waves are complex, soon plunging into rigorous calculus to describe volumes of water and shapes of swells. The language of waves, however, is simple and often poetic, it seems to mimic the hissing sibilance of the phenomenon itself: surf, set, swell, spume, spray, spill, seiche, spindrift– even the dread tsunami.

Those last, the unquestioned kings of wavedom, are often erroneously dubbed "tidal waves." In fact, they have nothing to do with tides. Tides are massive, large-scale movements generated by the gravitational forces of the moon and, to a lesser degree, the sun. Waves may interact with tides but are nonetheless almost entirely products of the winds. The only exception: the fierce tsunamis, capable of traveling vast distances at 500 miles an hour, are caused by undersea earthquakes or landslides.

Following the 1964 Good Friday earthquake in Anchorage, Alaska, a tsunami obliterated the small fishing town of Valdez (which was relocated, later to become terminus of the Alaska pipeline.) Hours later, thousands of miles down the California coast, the Alaska-spawned waves were still so strong that they tossed abalone into the streets of Monterey and set that town's bay rocking for days in the standing swell called a seiche.

Keats also praised the "eternal whisperings" of waves. In fact, waves do offer a unique aural mix. The sound is basically a version of what acoustic engineers dub "white noise," of a random mix of frequencies. But unlike the slightly discomfiting hiss of, say, an untuned radio, wave noise has a fairly regular yet slightly random modulation. "It's sufficiently irregular to be fascinating," says Walter Munk, a wave-studies pioneer at Scripps Institution of Oceanography. "Not so irregular as to be disturbing, not so regular as to be boring."

Not everyone has a beach at hand, so by now there are at least a half-dozen tapes and compact disk recordings of ocean sounds. One of the first, Nature Recording's 5-year-old *The Sea*, sold 44,000 copies in one year. You can buy the sound of waves on rocks, waves amid driftwood, waves on sandy beaches, waves punctuated by gulls, bells or foghorns. There are even competing schools of wave recording: live and unmodified versus a studio-polished mix.

Curiously, the mathematical understanding of waves came well before scientists really began to study waves in the wild. Victorian scientists were well advanced in the mind-numbing equations of fluid mechanics, but it took another century–and specifically World War 11–for wave scientists to get their feet literally wet. In the Pacific, European, and North African theaters, the Allied strategy sometimes depended on amphibious assaults–putting troops ashore with boats or armored landing vehicles. But heavy surf could create death by drowning even before the fighting started, or produce a squad of soldiers tumbling into enemy fire thoroughly seasick.

Researchers like Scripp's Walter Munk were among the first to develop ways to predict waves, based on complex readings of shoreline structure, tides, and weather. Although crude by today's standards, the highly classified wave work was crucial. During the first winter landing in North Africa, scientists managed to pick two relatively calm days on beaches that usually presented forbidding waves. And for D-Day in

Californian Michael Rogers, a novelist and senior writer for Newsweek, watched many waves in preparation for this article.

The article originally appeared in the August-September, 1992 issue of National Wildlife, a publication of the National Wildlife Federation, and is reprinted here with their permission.

Europe, prognosticators warned Dwight Eisenhower that the wave pattern looked rough. But delay was even more dangerous, so the invasion went ahead, encountering the tough conditions predicted. By the early 1950s, wave prediction proved a tactical device: Douglas MacArthur's amphibious attack at Inchon during the Korean War surprised an enemy unaware that the tides and waves even permitted such a landing.

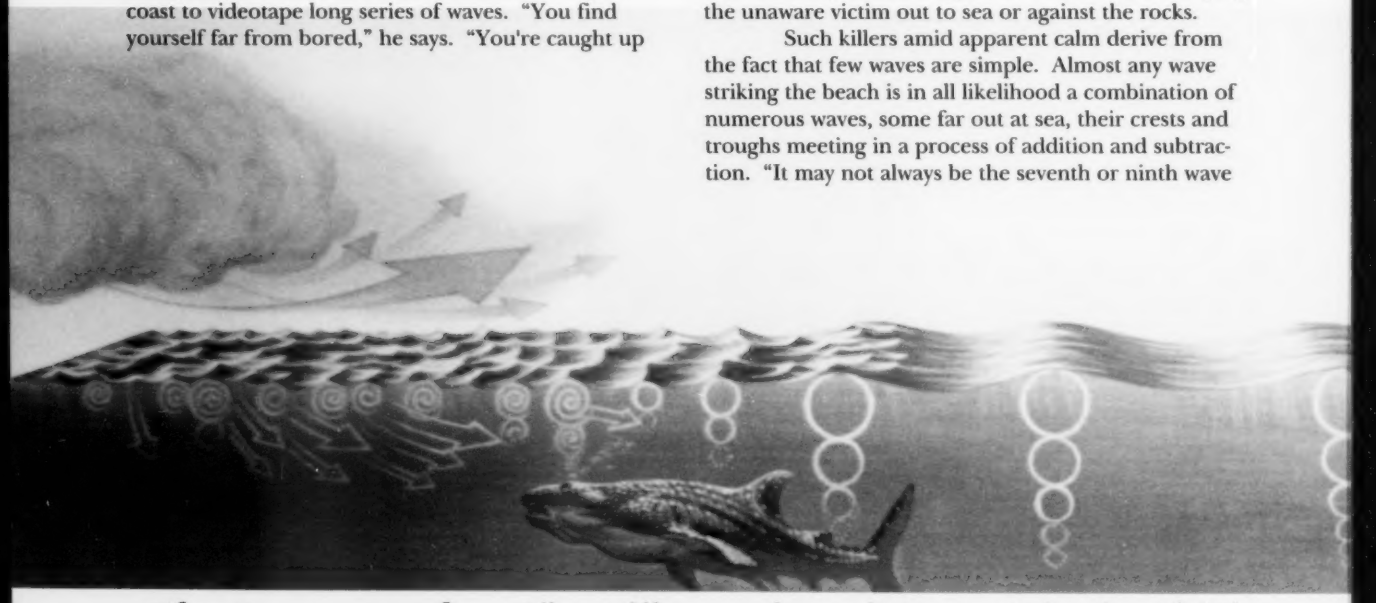
To sharpen predictive skills just after World War II, the Navy financed extensive hands-on wave measurement off the Oregon coast by a team of University of California researchers, headed by John Isaacs and including Willard Bascom, now a grand old man of oceanography. The team used huge military vehicles called dukws, built with six wheels and a propeller, to drive out through the shallows into monstrous breakers to make observations and install measuring devices. The crews would then promptly turn the vehicles around in the pounding water and half drive, half surf, always on the verge of swamping, back to the safety of the beach.

"Don't expect us to come rescue you if you get in trouble," the local Coast Guard warned the scientists. "We didn't," Bascom recalls. "We would have drowned long before they could have launched a boat." Indeed, at one nearby lighthouse, winter waves pounded with such force that sometimes the "flung spray" broke windows 135 feet above sea level. "Oregon spray," observes Bascom, "is a thing to be reckoned with." And also something not forgotten: Even nearly 50 years later, Bascom still visits the Oregon coast to videotape long series of waves. "You find yourself far from bored," he says. "You're caught up in it, always trying to guess what the next one will be like."

*A view from the bridge of the escorting **U.S.S. Greer**, shows a merchant ship steaming in stormy North Atlantic waters in June 1943. The two vessels were part of a convoy. Photograph courtesy of the National Archives.*

No matter how long you watch, predicting specific waves is maddeningly difficult. Surfers and beachcombers may gain a pretty good sense of what to expect in a given set of waves, but there's rarely an entirely dependable sequence—no magical "seventh wave" or "ninth wave" that's always the biggest. The result of this unruliness can be lethal. Along the rocky coast of northern California, Oregon and Washington—meccas for devoted wavewatchers—there are invariably three or four deaths a year attributed to "killer" or "sneaker" waves. The killer may appear out of a relatively calm sea, typically on nice days, sweeping the unaware victim out to sea or against the rocks.

Such killers amid apparent calm derive from the fact that few waves are simple. Almost any wave striking the beach is in all likelihood a combination of numerous waves, some far out at sea, their crests and troughs meeting in a process of addition and subtraction. "It may not always be the seventh or ninth wave



The Anatomy of Coastal Waves

When wind blows across the water, friction causes ripples to form. If wind strength is sufficient and prolonged, the ripples develop into a "sea wave" that lasts at least 5 seconds. As the forming waves leave the "fetch," they organize into even lines of swells radiating toward the shore. As they move, swells cause surface water particles to spin in a circular orbit maintaining

that's the big one," says Steven Webster, education director of the Monterey Bay Aquarium. "The combinations are so complicated that it may turn out to be the 251st." Which, very rarely, may also turn out to be a killer. Webster's prescription for safety on rough beaches: Sit above the tidal zone and observe the patterns of the waves for ten minutes or so before proceeding—and even then, never turn your back on the sea.

The biggest sleeper waves of all are found far at sea: full-size ship killers. These leviathan waves, implicated in dozens of mysterious mid-ocean ship disappearances, are again the chance coincidence of various crests and troughs all adding up to one monstrous construct. The towering wall of water can easily sink a ship 500 feet long and weighing many tons. "It's the trough that kills you," says Willard Bascom. "The bow drops away, and then the wave comes straight across and cleans the wheelhouse off the deck." Recall the weight of even the Monterey Aquarium's tiny pet wave; now consider the heft of a wall of water 112 feet high—the tallest wave thus far reliably measured at sea. Experts suspect killer waves that leave no witnesses may be nearly twice that record.

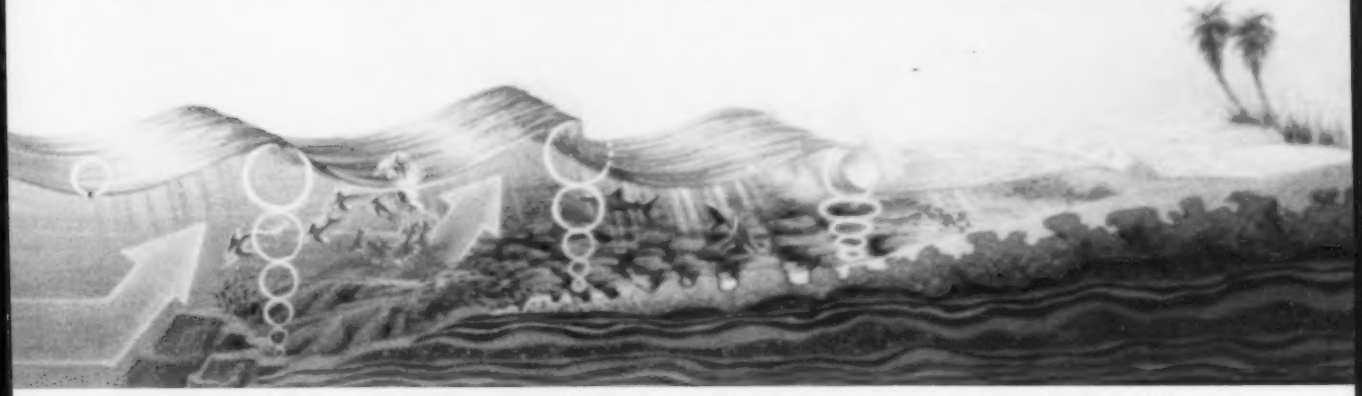
But waves produce far more life than they take. In fact, on shorelines, wave action contributes more energy to the ecosystem than do the direct rays of the sun (the waves themselves, of course, are indirect results of the sun). Some of the energy is actually heat—breaking waves do create friction—but because of the volume of water involved, the resulting temperature rise is negligible. What is not negligible is the sweep and power of the water itself. For denizens of the interface between ocean and shore, waves are an energetic, multifaceted benefactor.

There's meal service: waves deliver fresh portions of rich ocean broth for the filter-feeding mussels and barnacles. At the same time a wave may knock a loosened limpet into the center of a hungry sea anemone, or unearth a luckless sand crab for a vigilant shorebird or a surf perch. Waves oxygenate the shallow waters, of course, but they also actually help organize communities. Feather boa kelp and sea palms, for example, adapted to withstand pounding, grow on the ocean-facing sides of rocks; barnacles and mussels colonize areas of less turbulent backwash. Finally, waves help propagate species—from distributing algae spores to carrying Southern California grunion up a moonlit beach to bury their eggs.

Waves, given their random complexity, are yet only partially understood. Engineers building piers or jetties still run into unpredictable situations— disappearing beaches or sudden new sandbars. Biologists now suspect that migrating whales may ride beneath deep water swells to speed their passage. Oceanographers have lately noted that the waves off the coast of England have grown taller over the past few decades, for no apparent reason. And the crucial business of wave prediction still has some distance to go.

But change is coming. Walter Munk recalls a breakthrough experiment during the 1950s that used ships and land-based stations to track a single wave disturbance for 2 weeks, from its genesis off the coast of New Zealand to Alaska. "It took forever to do that experiment," he chuckles. Today satellite-based radar can do the same job effortlessly, even through layers of clouds. "In another five years," Munk says, "you'll be able to get a reliable wave forecast for anywhere in the world."

Except, of course, you probably won't want one for that isolated beach where you go to contemplate the universe, soothe some heartache, or simply mull the swells. After all, when the science is over, the final sweet consolation of waves is simple: Each one is slightly different—and there will always be another.



wave motion. As the particles go down, their orbit diameter decreases. Heading into shallower areas, the swells slow down, their wave length shortens, and they grow steeper in height, as less water is available to fill in the crest and maintain a symmetrical shape. The increasingly shallow bottom prevents the complete rotation of the circulating water particles and causes the waves to become unstable. They peak up and break, crashing near the shore in a foamy surf. Artwork by Phil Roberts, P.O. Box 3394 Manhattan Beach, CA 90266; (310) 374–2970.

Shiphandling in Heavy Seas

Captain Jeffrey W. Monroe
Massachusetts Maritime Academy

I will always remember my first real blow at sea. Helpless and at the mercy of the elements, we were embroiled in a typical winter storm off the southern coast of New England, and we had been battling wind and seas for what seemed to be many days. As a young third mate it was apparent to me that things were serious when I showed up for midnight watch and 2 inches of water was sloshing around in the wheelhouse

What impressed me the most was not the damage the storm had inflicted on the ship or even the tons of water that crashed on deck and tore at every bit of steel structure. It was the continual test of will between the sea and the ship's master.

For over 36 hours, the captain battled the storm, turning the ship's head in relation to the waves and adjusting the speed to keep our 30-year-old ship from breaking apart. Eventually his tenacity paid off, and we came out of it with only a few missing life rings. Later in port, we observed other ships that had weathered the storm. Most had experienced substantial damage from missing lifeboats to bent masts.

Like Captain Monroe, David S. Crestin of NOAA vividly remembers his first encounter with rough seas. He was a young ensign and navigator aboard the 450-foot U.S.S. ***Protector****, a converted Liberty ship on radar picket duty, about 400 miles east of Cape Cod during the infamous March 1962 storm. He took the photo above when wave heights were estimated at 60 feet. He recalls the experience: "We were wrenched and lurched over the 4-day period, which instilled a lasting and deep respect for the sea. The fact that we lost steering for a period, and actually became broadside to the monsters, is an experience no member of the crew will ever forget since we almost rolled over. The word put out that afternoon was that the bridge inclinometer registered 53 degrees. To this day I believe it; I can still feel how tense the situation was as the ship seemed to waiver ever so slowly before it came back."*

Warren Bolster

Above, a helicopter view of the Pipeline in Hawaii illustrates the effect of shallow water. Below are rhythmic swells which often appear along the California coast in winter.

Eventually, every master will experience the same type of trial in their professional careers. Most have the benefit of years of experience to draw upon but as the profile of the modern industry changes, these same responsibilities are falling to a younger generation with less lifetime exposure.

While there are no absolutes in regard to handling vessels in heavy seas, guidelines can be developed in order to minimize damage in these situations. These should be based on a fundamental understanding of how different wave systems influence a ship's seakeeping capabilities.

Causes and Effects

The irregular appearance of the sea is generally the collective result of several wave trains with different wave lengths, heights and direction of movement.

Captain Jeffrey Monroe is the Director of the Center for Maritime Training at the Massachusetts Maritime Academy. He is also an Associate Professor of Marine Transportation and Electronics. Jeff coordinates the armed forces education program and weather observer training. Captain Monroe is a 1976 graduate of Maine Maritime and has a master's degree in Transportation Management from the State University of New York. His sailing experience includes tankers, tugs, research and training vessels, and he has served in all capacities as Deck Officer including Master.

Captain Monroe is also involved with several maritime preservation groups including the Maritime Industry Museum, the Lightship Nantucket, and the American Victory Mariners Memorial Museum. His professional memberships include the Council of American Master Mariners and the Propeller Club of the United States. He is also the author of several student texts and is a contributing author to the Merchant Marine Officer's Handbook.

The irregularity of these patterns depend upon how the different wave trains interact. The wind is the generating force behind open water waves and the intensity of the sea is linked to the wind's speed, duration, fetch, influence of ocean currents as well as the configuration of the sea bottom.

The intensity is most noticeable near the center of the storm where the wind blows at increasing strength for a long period of time. The seas build up from a large number of separate wave components traveling in different directions. This creates an intense pattern of waves with short lengths, commonly referred to as a confused sea.

As the wind begins to decrease and the waves travel away from the center of the storm, the ones with the shorter wavelengths weaken and eventually die out. However waves with long lengths remain, often traveling long distances from the source. Sometimes similar wave trains with long lengths will combine which may increase the wave size, or in some cases, decrease it, depending upon whether the separate trains are in or out of phase.

Swells resulting from these long wave trains become more regular in their traveling pattern and tend to move in the same direction. Eventually, even these wave trains die out growing flatter and longer. The swell and waves are further affected by opposing winds which accelerate this decaying process. Roughly, the waves lose a third of their height when they travel a distance in nautical miles equal to their wave length in feet. However, this process causes the apparent period, length, and velocity to increase.

These waves eventually reach shallow water where the bottom restricts the motion of the water and the waves slow down. At this point, the wavelength decreases but their height increases. When the height/length ratio reaches an extreme point, the wave will break. This can also occur in deeper water when the waves meet a strong opposing current or wind

Warren Bolster

gust. These are seen as white caps and generally are present when the wind speed exceeds 12 knots.

Handling the Ship

As the ship travels, the waves cause it to heave, sway, and surge. They also cause rotational motions in the form of pitch, roll, and yaw. The hull is subjected to bending and racking stresses which increase as the seas build. When the relative motion between the ship and the waves become significant, the vessel will ship water on deck and may begin to pound. This effect can not only damage the cargo and increase discomfort to the crew but can also cause substantial damage to the ship's structure. While every ship responds differently, some actions can be taken to reduce the ship's response to the seaway and minimize these effects.

The master can deal with heavy seas through changes in the vessel's course, speed, or draft. Usually this is done through trial and error or through judgment based on previous experience in a similar situation. The master can develop a system to record the vessel's response to different situations and then use this system to make efficient decisions. Then he can determine if a change in course rather than a change in speed would be more appropriate for that

The Last of the *World Glory*

The first supertanker in the Niarchos fleet, the ***World Glory*** was only 14 years old when it was destroyed by devastating *Cape Rollers* off South Africa. The vessel was travelling from the Persian Gulf to Spain via the Cape of Good Hope. Seaworthy (it had recently passed an ABS inspection) in all respects, it had a competent, experienced crew to carry the cargo of crude oil.

When the ***World Glory*** was off the southeast coast, Capetown Radio warned of strong southwest winds and rough seas, followed by gale warnings for the area to the south. When the storm hit, speed was reduced to slow, and the ship was kept headed into the wind and sea. As the southwest wind increased, the waves built up into the awesome 50-foot *Cape Rollers*. The ***World Glory's*** king posts were reported level with the tops of the waves, which were described as steep and two-thirds the ship's length. The ship did not roll but pitched into the seas, taking masses of green water over the bow and shaking it off gamely. The skipper reduced the speed to bare steerageway, holding the bow directly into the sea, and waited for the storm to blow itself out.

Ten hours later, the ship buried its bow in an enormous wave estimated at 70 feet. As the huge wave passed under the ship amidships, the bow and stern were left unsupported, causing a tremendous hogging stress on the upper deck. Their weight caused the upper deck to crack aft of the bridge. Another massive roller swept under the vessel raising its bow sharply skyward and causing a terrific reverse or sagging stress on the ship's bottom. The ***World Glory*** shuddered violently and split in two. Oil spilled into the sea and was set afire by the mixture of oil, kerosene, and gasoline.

Many of the crew perished in the violent breakup, but a few managed to gather in the wheelhouse and parachute flares were fired. They were also unable to launch a lifeboat. The skipper was washed overboard and lost. Miraculously 10 survivors were picked up by four rescue vessels after being in the water for 18 to 24 hours.

Questions were raised about how to avoid similar casualties in the future. While it appears that everything that could have been done was done, two things come to mind that might have helped. One is the particular condition called "synchronism," and the other is an MSTS skipper's "Typhoon Doctrine."

A ship experiences synchronism when its rolling or pitching period coincides with the wave period. When this occurs the ship may, in the extreme situation, roll over or dive into the seas violently. While the ***World Glory*** was not a case of synchronism, if the great height and long distance between waves could have been anticipated as an extreme hazard, consideration might have been given to altering course to change the ship-and-sea relationship. This danger can be avoided by either changing course or speed, or both.

The tanker had ample sea room (30 miles or more). The Typhoon Doctrine advises that "if the wind force rises to 60 knots or more and the sea becomes confused, stop your engine, drift and wait for the storm's dangerous area to pass before you proceed." This should be done only if the ship is stable and watertight. Perhaps ***World Glory*** might have survived if its engines had been stopped and it had been permitted to drift and find its own best position in relation to the seas as a dead ship. While this is mere conjecture, particularly because it encountered a gale with wind and sea constant from the same direction rather than a tropical storm, this casualty vividly highlights the need for eternal vigilance in sailing and the importance of maintaining a healthy respect for the elements. In these days of super ships, efficient weather predictions, and instant communications, we may forget that a ship is still very much on its own at sea.

Krister Brzezinski

*The 11,736-ton Swedish cargo vessel **Winter Water** pounds into heavy swells during Tropical Storm Georgette on July 28, 1980. It reached hurricane strength the following day in the eastern North Pacific where nearby vessels were reporting 20- to 30-foot seas.*

particular vessel.

The master must take into account significant wave heights, mean wave period, the directional spread of the various wave trains, and the speed/direction of the current and wind. In addition, the effect on the ship's size, shape, condition of load, speed and relative heading to the waves must be considered.

Small ships, for example, experience much more motion than large ships. In long swells, larger ships experience more bending stress than smaller vessels. Ships with lower superstructures and deeper drafts are less affected by the wind.

In most situations, adjusting the speed or the course affects the frequency of the ship's encounter with the waves. This will prevent the ship from panting or pounding in the seaway.

Different ships have to consider different guidelines. Tanker masters find the effect of roll less significant than masters of container ships. A tanker's roll can be reduced by minimizing free surface effect through pressed-up tanks. Sloshing of cargo or ballast in tanks causes more discomfort than damage. Sloshing is a problem on LNG ships, however, where tank structural damage and product loss can occur.

Also, shipping water can be more noteworthy on tankers because of the amount of deck structure and the generally low freeboard. Slamming into the seas can be reduced by increasing the amount of ballast when no cargo is carried. Most important is how the vessel rides in long wavelength seas which can introduce bending stress and has caused foundering. Keeping the vessel relative to sea so that waves do not support the ends while leaving the center with less buoyancy will prevent this. These same guidelines are applicable to bulk carriers.

In dry cargo ships, rolling can cause cargo shifting and loss of stability. Shipping of water can damage hatches and slamming shock waves can break cargo and damage the ship's structure and hull. In Ro-Ro ships, rolling can compromise lashings on vehicles and slamming can cause significant ship damage because of the vessel's unique construction. Shipping water is a more noticeable problem when deck cargo is carried. Car carriers are handled in a similar manner but additional consideration must be given to the impact of the large superstructure which can be more

C. Patrick Labadie

*Heavy seas on Lake Superior wash across the Laker **Joseph M. Thompson**. The Great Lakes are certainly not immune to rough seas and freak waves as those who have studied the **Edmund Fitzgerald** case can testify.*

easily subject to the effects of wind.

Research vessels have a tendency to be small but generally have large amounts of deck equipment which can be easily damaged by shipping water and excessive rolls. Tugs with tows have to take into account the strain on towing gear because the tug and the tow are affected separately.

Finally, passenger ship masters find that not only is their cargo delicate but often temperamental. Any motion which causes discomfort to passengers must be dealt with.

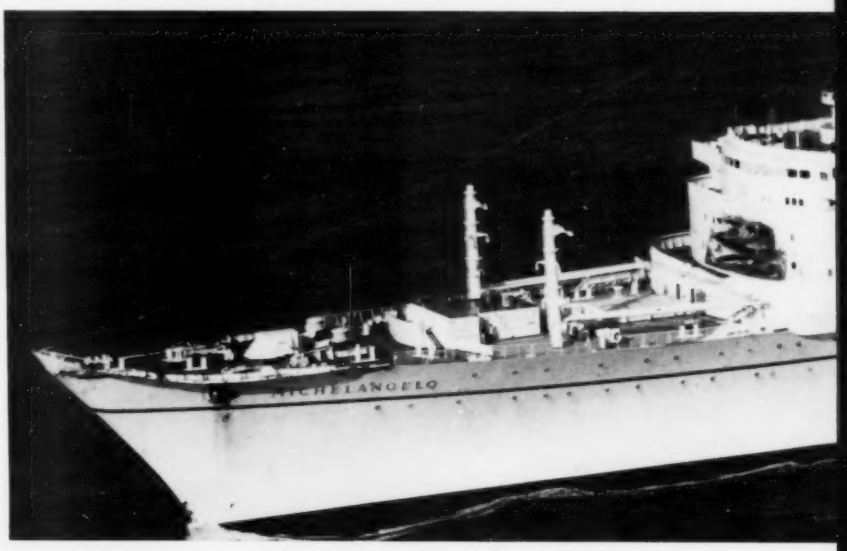
Every master should compile a collection of information on the vessel they serve from which a set of tables or other similar guidelines can be derived. As a company policy, the information can be consistently compiled and maintained by whomever serves in the master's position. The tables or data should be organized to reflect the affect of speed or course change on roll, approximate vertical acceleration at the forward perpendicular, relative motion in the seaway, approximate vertical bending moments and approximate torsional moments. These should be related to short, medium and long wave periods.

In addition, the master should keep notes in regard to the vessels' reaction to unusual sea conditions, particularly when freak waves are encountered or when carrying unusual cargo. A logbook with copies of weather reports after encountering storms has also proven to be useful.

There is also some research available for vessel operators. This includes casualty reports available from the U.S. Coast Guard and research reports available from Det Norske Veritas.

Ultimately, any information that helps a captain deal with heavy weather and seas will be useful. There is really no substitute for experience, but good information reduces the amount of trial and error and may help avoid a wrong decision. Anything that contributes to the safe passage of a vessel is worth looking into and if in your voyages you run across unusual weather or seas, don't forget to report it to the weather service. That helps everyone.

*On April 12, 1966, the 902–foot **Michelangelo**, some 600 miles southeast of Newfoundland, was battling a North Atlantic storm with 20– to 30–foot seas. Suddenly a huge wave towering above the others smashed into the **Michelangelo** inundating the forward half of the ship. Steel superstructure gave way, bridge windows 81 feet above the waterline were smashed, furniture in the public lounge flew through the air, heavy steel flaring on the bow was torn off and the bulkhead under the bridge was bent back at least 10 feet. Three people died and twelve others were injured in the incident. The **Michelangelo** is seen here limping into port, and some of the damage is noticeable.*



U.S. Coast Guard

Night of the Monster Waves

Jerry Nickerson

Without warning, two or three 10- to 18-feet high freak waves smashed ashore in Daytona Beach, Florida. The waves rolled in about 11 p.m. July 3, 1993 north of Cape Canaveral, and long-time residents can't remember anything like this happening before.

The City of Daytona Beach has long allowed people to park their cars at night on the broad, nearly level expanse of hard-packed beach. The night of the freak waves arrived with balmy breezes and a low rippling surf.

Sergeant Bill Marshall of the Volusia County Beach Patrol was driving north in his squad car, a Jeep Cherokee, along the area between the parked vehicles and the surf line. Suddenly, he saw a "wall of white water 10 to 18 feet high" careening toward him. Before he could react, the wave rolled over his vehicle and for a long moment he was under water. When he popped to the surface, his jeep was being surfed into cars farther inshore.

Roy Bennett and his wife scrambled for the boardwalk as the waves plowed parked cars towards them. They just made it as seven cars jammed into the approach ramp at the Main Street Pier.

One hundred vehicles were slightly damaged while 20 people received minor injuries. No fatalities resulted from the freak waves.

Afterward, Chief Ranger John Kirvan while surveyed the damage, and said, "We are truly lucky this thing happened at 11 p.m. Friday night and not 11 a.m. this morning. We'd be counting the dead if it had."

Jeffery List, an oceanographer from the U.S. Geological Survey office at St. Petersburg, Florida, and assistants soon arrived to investigate. They found high water marks at least 7 feet above sea level just south of the Main Street pier. About 15 miles south of New Symrna Beach, they found water marks at 4 feet above sea level. About 7 miles north of Daytona Beach, the survey was equally disappointing since rain had erased the water run-up marks. There hadn't been any wave sightings farther to the north because few, if any, people walked the beach in the rain that night.

The tide gage report from St. Augustine, about 75 miles north of Daytona Beach, showed several large peaks and troughs that could have been from the same wave train that struck the beach. It appears that the freak waves may have extended even farther north. To the south, they extended beyond New Symrna Beach, possibly to Cape Canaveral.

Initially there was some confusion about the exact time the wave struck. The National Weather Service and the NOAA tide gages report observations in standard time while the rest of the world uses daylight saving time in July. Consequently, the waves seen on the St. Augustine tide gage were at the same time as the wave incident at Daytona Beach.

Many possible causes for the freak waves were advanced. A underwater landslide as cause was discarded for two reasons. First, it would have to be along the continental slope and the slope itself would protect areas to the west. Second, the landslide would have to extend from St. Augustine to New Symrna Beach. Such a large earth movement would have been detected on seismographs, but it wasn't. This left the freak storm theory with thunderstorms, squalls, and downbursts. The Weather Service Office at Daytona Beach produced some sketches of radar echoes along the Florida-Georgia border. These echoes lasted only 3 hours, and there were no wind reports of over 10 knots in the area. There was, however, a line of thunderstorms about 430 miles east and parallel to the coast of Florida on the morning of the 3rd.

It was suggested that somewhere between the continental slope and where the "wall of white water" was seen there were a series of green water waves of equal height or higher that broke and formed the foam-laden runup that came ashore. Water weighs about 63 pounds per square foot; casual estimates of the force of a "10- to 18-foot" wave of green water doesn't fit the damage done to the vehicles or the shoreline. Quite fortunately, what hit Daytona Beach appears to be the last foamy remnants of waves that broke well offshore.

Could it happen again? It appears that this was an unusual combination of many physical circumstances that had to occur in precise sequence. The opportunity for recurrence is probably very small. However, never say never about natural phenomena that are not fully understood and so poorly measured.

Freak Waves!

Jerome W. Nickerson

Ancient mariners, believing the world was flat and of very limited proportions, navigated by landmarks. Their maps were very pictorial but not very accurate. On the edges, they drew fanciful pictures of dragons and other sea monsters, perhaps representing encounters with large fearsome waves of the open ocean.

Most large wave stories were treated as impossible exaggerations until the ***U.S.S. Ramapo*** encountered an enormous wave in 1933. A qualified observer measured a wave 112 feet high by triangulation. Doubters have reexamined the mathematics of that incident since the details were first published. However, it is somewhat of a moot point because other incidents of very large waves have been published with increasing frequency since that time.

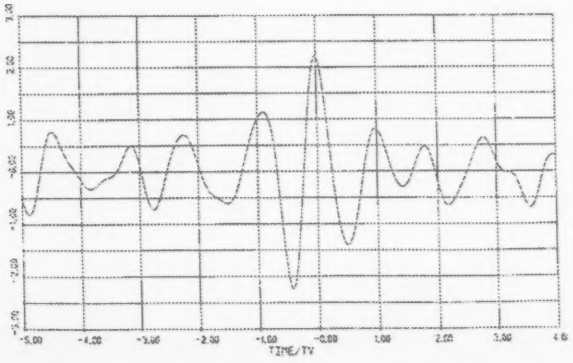
In any seaway where the wind is actively forcing waves, many groups of waves exist at the same time. When high waves in two wave trains coincide, as they frequently do, it is not unusual for a wave of short duration to reach a peak of twice the height of the other waves. These are not freak waves but ones that occur regularly at sea. The characteristics that set a freak wave apart are its extreme height and the extreme depth of the trough. A freak wave occurs with almost the same or even a shorter wave period as other waves in the seaway.

Experience and wave tank experiments have shown that long wave trains are not uniform but tend to continually change and reform themselves into groups. These trains travel at a group speed, which is one-half the speed of individual waves in the group. Each wave forms at the back of the wave train, travels through it, and disappears at the forward edge. The waves start low, build to their maximum height in the middle of the train, and fade as they approach the forward edge.

In the study of freak waves, it is important to determine if the incident is the result of the wave or the result of a vessel's interaction with a wave. Was the

A wave with Extreme Storm Waves (ESW) characteristics was encountered by the m.v. ***British Wye*** *in a winter storm south of Newfoundland. The photograph is courtesy of Captain J. F. Thomsen.*

Below is a time history of a freak wave with deep troughs both ahead and behind the principle wave.



Jerome Nickerson was a naval officer, meteorologist, oceanographer, and a civilian researcher before he became the Marine Observations Program Leader at the National Weather Service (NWS). Since his retirement from NWS, he has remained active as a Marine Meteorology Consultant in Portsmouth, VA.

vessel's speed or heading the cause of the incident, or would it have occurred had the vessel been dead in the water? Sometimes a vessel's speed or heading worsens the wave impact and contributes to the damage.

While there is a lack of abundant data, most freak wave reports mention:

- A steep-sided deep trough ahead and/or behind the freak wave, often reported as "a hole in the sea."
- A wave that is considerably higher is often described as "a wall of water."
- It is usually level-crested to the right and left for a considerable distance, sometimes "extending from horizon to horizon."

Extreme Wave (ESW)

Extreme Storm Waves (ESW) generally describes waves that develop within a storm. They are also called freak, rogue, or episodic waves. One difference between these ESWs and normal waves is the crest length. A normal wave decreases in height to the right and left so the highest part of the crest begins breaking first and initially spills forward and to the right and left of the wave track. The ESW, by contrast, is more level-crested and breaks forward with equal energy all along the crest.

ESWs can occur as single or multiple waves usually in groups of three, often referred to as "Three Sisters Waves." Freak waves have been detected and followed on radar for 10 to 50 miles, but without enough detail to determine the type of freak wave. These waves could exist for more than an hour and explains how ESW can pass through a storm and approach a vessel from a direction different than the other waves in the seaway.

One of the worst nightmares on the bridge watch is to have a single or three sisters ESW loom out of the storm from abeam. The USGC icebreaker ***Polar Sea*** was off Vancouver Island heading southeastward when it was struck on the starboard beam by a Three Sisters ESW. The vessel was travelling into an increasing sea while a storm to the southwest was moving eastward. A hard core of probable thunderstorms had been detected in the center of this storm and tracked for over a thousand miles and 36 hours. The ***Polar Sea*** rolled violently, tossing people and anything not secured from side to side. One person was killed and several were injured (See "Three Sisters," *Mariners Weather Log (MWL)*, Fall 1986, Vol. 30, No. 4).

A freak wave occurred at the end of World War II and nearly sank the HMS ***Queen Mary.*** The ship, ferrying U.S. soldiers home from Europe, was south of Newfoundland and heading westward in an intensifying storm. Without warning, it was struck from the north by a freak wave of such size that ship's officers stated that the ship was within a degree or two of rolling past the point of no-return.

Hurricane and Typhoon ESWs

Tropical cyclone waves run the gamut from short-crested breaking waves to single and Three Sisters ESW. Their wind field is complex– circular with about a 15° inward slope and increasing in strength toward the center or eye wall. Thunderstorms, downbursts, and tornadoes are common in the feeder bands. These storms are often erratic in course and speed and should be given a wide berth. While the number of ships sunk is substantial, sorting out which were victims of ESWs would be an insurmountable task. An account of one such incident where an ESW struck a container ship as a typhoon approached is described in the *MWL*, Winter 1983, Vol. 27, No. 1.

*A current ESW devastated the **Wilstar**. The Norwegian oil tanker was struck while transiting the Agulhas Current off South Africa on May 17, 1974. The $1.2 million in damage included the 1-inch thick steel hull plates which were torn like paper.*

Meteorological Bomb ESWs

A meteorological bomb is defined as an extratropical storm where the central pressure drops 24 millibars or more in 24 hours. It is the winter equivalent of a hurricane. This type of storm has rapidly increasing winds. The air temperature on the western side of the storm is usually much colder than the ocean which promotes turbulence and gives the wind more "bite" on the ocean surface. The potential for the development of ESW in a meteorological bomb is quite high.

Polar Low ESWs

In large winter storms there is a broad, massive outflow of cold air west of the storm center which often contains wind speed surge lines and squall lines. Some of the more intense squall lines may develop frontal characteristics such as wind shifts, increased wind behind the squall line, showers, and sometimes thunderstorms. Many smaller ships have been sunk by the combination of squall lines, winds, and waves. The British *aux barque* ***Marques*** (*MWL*, May-June 1980, Vol. 24, No. 3) and the U.S ***Pride of Baltimore*** (*MWL*, Winter 1987, Vol. 31, No. 1.) were both sunk by this combination.

Downburst ESWs

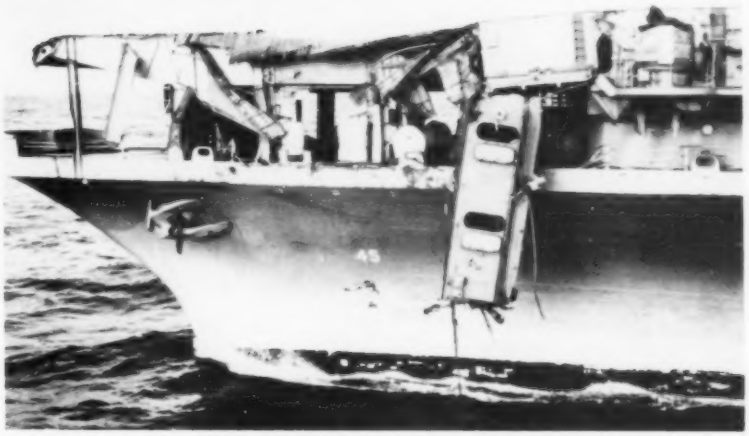
Using data published by Dr. T.T. Fujita, the author recommended applying downburst identification techniques at sea similar to those on land (*MWL*, Winter 1985, Vol. 29, No. 1). The development of downbursts is based on the detection of possible thunderstorms from satellites or radar. If the thunderstorm areas persist and move at about the group velocity of the wave train, waves could rapidly develop into the ESWs category. The incident with the ***Polar Sea*** documents a suspected long run of downbursts over the ocean. The freak wave incident at Daytona Beach, July 3, 1992 could also have developed from an area of thunderstorms and downbursts.

*The **U.S.S. Valley Forge**, an aircraft carrier, experienced a freak current wave during a winter Nor'easter off Cape Hatteras, NC (left). As it turned northeastward, it was struck by a freak wave that was twice the normal wave train height and then doubled again by the strong opposing current. Tons of green water crashed aboard and sliced the port side of the carrier flight deck off like a huge cheese knife.*

The photographs below show the damage. The forward parts of the flight deck with its steel girder reinforcement and 6–inch thick teakwood deck were snatched off and hurled to the bottom. Part of the Air Group Junior Officers' Quarters remain precariously attached but at an awkward angle. Fortunately, this section was not occupied during the incident.

Other waves do not fit neatly into the ESW categories, but their irregularities qualify them as freak waves: shoaling, current, landslide freak waves, and crossing wave trains.

Crossing wave trains will occasionally produce waves nearly equal to the combined height of the waves that make up the train. These trains, which are caused by refraction, often create rough seas around small islands. This should be a consideration when seeking shelter in the lee of an island. Other areas to avoid are shallow submarine banks and bars that reflect or refract deep water waves producing converging wave patterns.



Shoaling Freak Waves

Even in the time of the Phoenicians, there have been stories of extremely high waves (up to 100 feet) west of southern Europe especially in the Bay of Biscay. Apparently these waves originate from storms along the U.S. East Coast, Newfoundland, and Greenland, and if unopposed by wind fields can continue as swell and end up in the Bay of Biscay. The bottom of the bay rises quite suddenly to steep underwater cliffs at the

edge of the continental shelf. Water depth at this point is 100 fathoms (600 feet) so a wave with a 1,200-foot wavelength would "feel bottom" and start to rise into a breaker. (See pg. 35 for a mariner's description of these waves.)

These shoaling waves are steep-faced swell-type waves that rise out of the sea from the west and travel quite a distance to become one of the world's biggest breakers. The swell continually increases in length with a proportional decrease in height. The energy of a swell several feet high with a wave length of 1,000 to 1,500 feet and travelling at a speed of over 50-knots is enormous. However, in the open sea they are insignificant mounds of water with little slope, usually undetected by shipboard observers.

Many other areas of the world experience shoaling waves; dangerous waves frequently occur west of Ireland and Scotland during the winter. The U.S. West Coast and, of course, the northern coasts of the Hawaiian islands also are visited by high waves.

Current Freak Waves

Currents over 4 knots exist in many areas over the ocean, and when these currents are opposed by wave trains, the waves increase by as much as twice the height of waves outside the current. When the occasionally higher than normal wave is factored into the opposing current situation, waves can reach four times the height of waves outside the current.

For instance, in a Nor'easter off the eastern U.S., waves of 20 to 30 feet are common while a 40- to 60-foot wave will occasionally appear. Shift the Nor'easter over the core of the Gulf Stream, which has current streams of 4 knots, and the potential exists for an 80-foot wave.

The Agulhas Current, off the eastern coast of South Africa, and the Kuroshio Current, southeast of Japan, are other areas where opposing current waves are particularly famous for smashing supertankers.

Landslides

Landslides can occur both above and below the water surface. J. LeBlanc describes how an estimated 90 million tons of ice and rock broke loose from a 3,000-foot high glacial precipice and plunged as a single mass into Lituya Bay, Alaska (*MWL*, Winter 1987, Vol. 31, No. 1). The wave raised struck the mountains on the opposite side of the Bay so hard that it scoured the hills to bare rock and took the trees, all vegetation, even the earth itself to a surveyed height of 1,720 feet.

There have been many less spectacular incidents. A sport fisherman, fishing off Baja California, suddenly heard a sound similar to a boat running aground on a rocky reef. At the time, he was over sandy bottom with plenty of water under the keel. Astern, to the north a single wave rose rapidly out of a glassy sea. His first instinct was to race for deeper water. If caught in the shallows, his boat could be dashed onto the rocks and coral protrusions. He raced westward as the wave continued to rise. Finally, he turned the boat into the wave and met it bow-on at nearly maximum speed. The bow continued to rise until it was tilted upward at about 45° to 50°. Suddenly, the bow broke through the wave and sent the boat airborne. After a short flight and crash landing, the fisherman discovered there was no apparent damage. By the time the people aboard had gotten back to their feet, all traces of the freak wave were gone, and the sea was once again glassy calm.

In another instance, a whale-watching trip to the southeast of Block Island, RI almost ended in disaster for a group of school children. The boat, a 110-foot aluminum hulled converted sub-chaser, was headed south several miles east of the island when someone spotted what appeared to be the wave of another vessel near the island. It was unusual in several respects. First, it was a clear day with little wind and wave activity, and no other ships visible that could have caused the wave. Second, there was only one line of waves. Finally, the waves weren't very high, but they moved rapidly toward them.

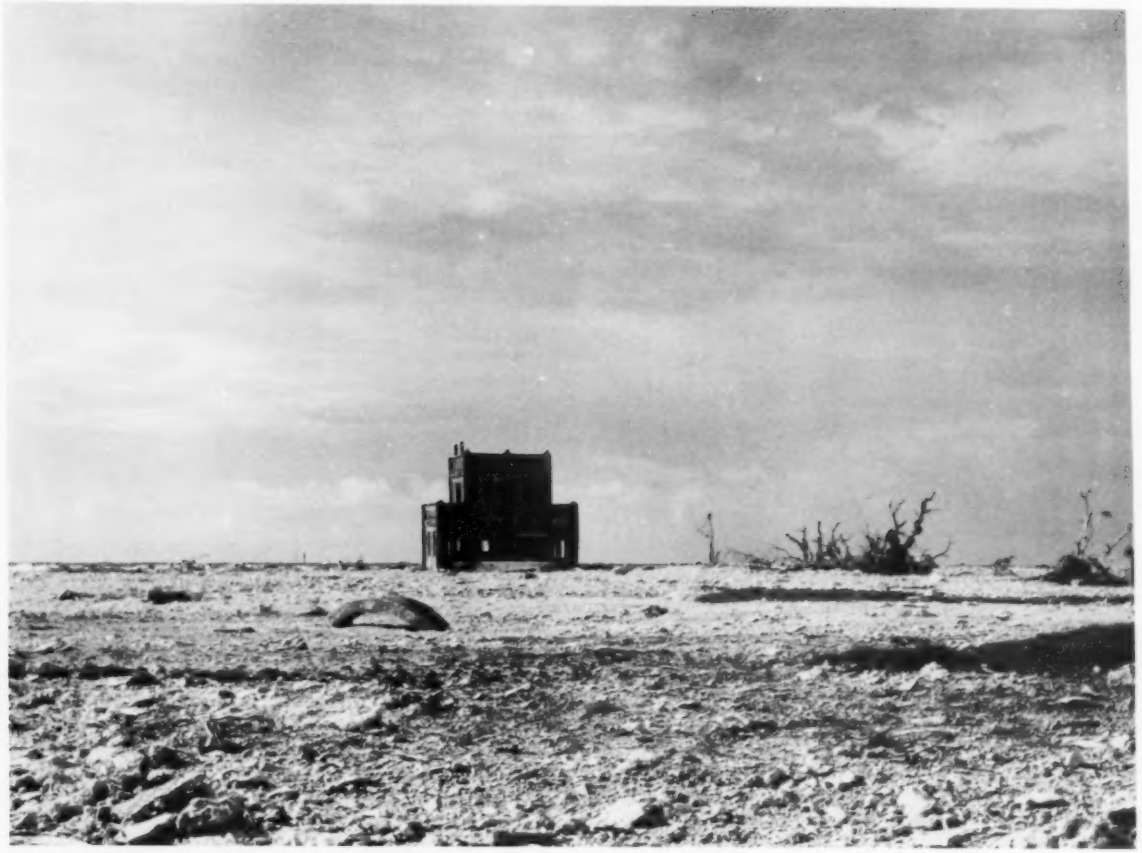
As the waves got closer, the captain could see two parallel waves about 3-4 feet high with a darker area about 20-30 yards wide between them. He turned slowly to the west to meet it bow-on as a precaution. He soon saw that it was a deep trough– a huge trench– several miles long.

Another observer estimated the trough to be at least 40-feet deep. The bow pitched up slightly over the lead wave and then fell to "at least a 50°or 60° down angle" before being buried in the incoming wave. It came up rapidly, so they took only a little water. Only one of the passengers was washed over the side but was quickly rescued. Several passengers suffered broken bones and a multitude of abrasions and bruises. No one noticed where the freak wave went after it passed the vessel. Later, scuba divers found evidence of an underwater landslide near Block Island.

There was no investigation into the California wave, but it would appear to have been caused by an underwater landslide which happens with regularity along the rocky West Coast.

Tsunamis

Tsunami is a Japanese word meaning "harbor wave." The U.S. researchers picked this name to replace the erroneous use of tidal wave. The great tsunami, a true freak wave is caused by an earthquake near or under the ocean. It is covered in other articles in this issue.



This Japanese blockhouse and others like it were the only structures on Jaluit able to withstand the surge and winds of Typhoon Ophelia. Jaluit is one of the Marshall Islands in the Ralik Chain. Ophelia was an unusual January typhoon. On the 8th of January 1958, a reconnaissance aircraft reported a surface wind of 150 knots. Less than 1 week later, a reconnaissance aircraft reported that it was about to enter the eye. It was never heard from again.

Hurricane Storm Surge

Like tsunamis, hurricane storm surges are also erroneously called tidal waves. In addition to the normal and freak waves particular to tropical cyclones, there is a mound of water called a storm surge that is a major cause of death and destruction in these systems.

While wind waves move water in small amounts at low to moderate wind speeds, at high winds speeds, the wind practically shovels the water. When the storm approaches shore, the water sinks and outflow becomes increasingly restricted. Eventually the water piles up vertically in a mound known as the storm surge. As the surge moves ashore, it provides a base for waves to move inland, sometimes, for over a mile.

The storm surge height is measured in still water which means the height of the mound of water without waves. Both waves and the storm surge relate to the speed of the wind exponentially. For instance, a category 1 hurricane on the Saffir/Simpson Hurricane Scale has winds of 74–95 miles per hour and a storm surge of only 4–5 feet. Category 4 has winds of 131–155 miles per hour and a storm surge of 13–18 feet.

Freak waves have always been with us, but it wasn't until unexplained weather losses of ships in World War II reached significant numbers that Great Britain began recording freak wave occurrences. In 1982, the author added the freak wave report to the U.S. Surface Weather Observation Report form. However, efforts to establish an archive for freak wave data from current ship reports have been unsuccessful. No one knows how much data is available. Research in this field of oceanography is needed to support marine architects, ship and oil platforms designers and the general public. The savings in casualty losses and the costs of over designing ships and structures would more than pay for the archives and the increased research it would encourage.

Solitary Waves

Lieutenant Commander Robert Irving, USN (Retired)

"It is pleasant, when the sea is high and the winds are dashing the waves about, to watch from shore the struggles of another."
–Lucretius, 99–55 B.C.

Many strange things occur in the broad reaches of the oceans and seas of the world. Among these are unusual waves. Some have been known and documented for hundreds of years; others have been the source for myths and sea stories for at least as long. Now that we are able to gain a truly global view of the planet through satellites, we are finding that many of the old salts' tales are quite true. Solitons, tidal bores, the great tsunamis and other freak waves continue to fascinate the scientists who study them and mariners who may experience them first hand.

SOLITONS

Solitons are isolated from other waves and do not travel in wave trains with a specific periodicity. Despite this lack of periodicity, solitons can cover long distances. They appear in two distinct forms: surface waves and internal waves. The surface soliton was recognized as a solitary wave in English canals early in the nineteenth century while internal wave solitons were only recently understood. Tidal bores, also a form of soliton, have a much longer history although they were not recognized as such until a mathematical formulation was deduced in the 19th century. The typical surface soliton is a pulse waveform whereas the bore is a step function, leaving a higher water level behind it than it initially encounters.

The most interesting solitons were discovered, (at least by Westerners) by the sailors on the tea clippers sailing through the Malacca Straits and the Andaman

This view (above) of Jamestown and the Harbor St. Helena in the South Atlantic was drawn by Lietuenant F. R. Stack of the St. Helena Regiment. It depicts the scene on February 17, 1846, a day on which thirteen vessels were wrecked by this extraordinary phenomenon known as rollers. Property damage amounted to £10,000. What was remarkable was that the agitation of the water was confined to about 500 yards from shore, beyond which distance the sea was prefectly calm, and there was little wind at the time. Photo courtesy of the Mariners Museum, Newport News, VA.

Sea to Foochow in China or back to England. These ships repeatedly reported "boiling seas" or "tide rips" in otherwise relatively calm seas which rose around the ship and then subsided. They were laughed at by most *knowledgeable* people. Satellite photographs, however, have shown as many as seven of the solitons crossing the Andaman Sea at one time, and photographs taken from the tower of a drill ship in that area clearly show the boiling seas effect. The Andaman Sea is a relatively shallow body of water bounded on the east by the Malay Peninsula and nearly closed on the west by a ring of islands. It appears that tidal currents forced between the islands excite solitons which propagate as internal waves across the Andaman Sea. The interaction of each internal wave with the surface of the sea produces a large number of small wavelets of random direction, hence the appearance of boiling. The drill-ship photos show the band of agitated water approaching and engulfing the ship and then dissipating. It is possible that this effect exists elsewhere, but remains unreported. Internal waves of substantial magnitude have indeed been detected, but these are periodic waves, not solitons.

TIDAL BORES

Another tidal-driven solitary wave is the tidal bore, known by many different names in various rivers of the world. In southern England it may be an *eagre*, on the Seine it is the *mascaret*, on the Amazon a *pororoca*, and on the Hooghly (or Hoogli) in India it is a *bahu*. Whatever the name, two elements are essential to the regular formation of tidal bores: (l) An ocean estuary which has a tidal range of some 20 feet or more, and (2) A river mouth which narrows and shoals in a rapid but regular fashion from that estuary into the river proper. Just as ocean swells pile into breakers when they approach a gradually shoaling shore, the incoming tide is piled into a wall of water which moves up the river as a single wave with a higher water level behind it. The Amazonian *pororoca* or "rock crusher" may attain a height of 25 feet and sound like distant thunder as it approaches. Bores normally occur most often at spring (large amplitude) tides, but they have been generated by a storm surge, which is a pseudo-tide caused by a combination of low barometric pressure and water moved by the wind.

Bores are most common in Great Britain and on the French coast adjacent to the English Channel and the Bay of Biscay. The Indian peninsula has a number of rivers with bores, as do China and Brazil. The only significant bores in the U.S. occur in Alaska's Cook Inlet. A bore called the "burro" driven by the Sea of Cortez in the Gulf of California used to run up the Colorado River but silting of the Colorado delta has nearly eliminated this bore.

However in Canada, the Bay of Fundy, known for its huge tides of as much as 50 foot, generates two bores– one on the Petitcodiac River in New Brunswick and the other on the Salmon River in Nova Scotia.

This tidal bore begins at Turnagain Arm. The photograph is by Julius Fritchen at mile 79 on the Alaska Railroad. The rate of advance of the bore is about 6 knots and sometimes the bore attains a height of 6 feet. Courtesy, Anchorage Museum, No. B67.23.28.

TSUNAMIS

Like the soliton, the tsunami is a solitary wave but of vastly different character and effect. A tsunami is a shock wave caused by an earthquake, which radiates in all directions from a submarine source at nearly the speed of sound in water. A tsunami warning network covers the Pacific Ocean since the tectonic *Ring of Fire* which surrounds the Pacific is a common source of undersea earthquakes. Because of the very high speed of the shock wave, a tsunami from an earthquake in Japan can reach Hawaii or the West Coast of the United States in a matter of hours. In deep water, a tsunami could not be detected in a choppy sea since the wavefront might be only 1 or 2 inches high. However, when the tsunami approaches a shoaling shoreline, all of the energy of the shock wave is compressed into a few feet of water, which can result in a wall of water 20 to 60 feet high being driven onshore. It has been estimated that the deepwater tsunami from the explosion of Krakatoa was as much as 1 foot high, yet it resulted in tidal waves as much as 140 feet in height which decimated many of the Indonesian islands.

Lituya Bay, Alaska

The earthquake-induced rockslide of July 9, 1958 at Lituya Bay generated a wave that surged 524 meters up the mountainside (above)– a 1,720-foot wave. The rockslide occurred at the head of the bay to the right and destroyed the forest (light-shaded areas) to an altitude of 1,720 feet. The photo was provided by NOAA'S National Geophysical Data Center.

Lituya Bay was also the site of an historical maritime tragedy involving not a solitary wave but waves that result when sea or swell meet strong tidal currents. The current at the entrance runs 5.1 knots on the flood and 4.1 knots on the ebb tide.

In 1785 Jean Francois De Galoup La Pérouse, a French navy officer, was placed in command of an exploring expedition designed to rival that of the English Captain Cook. His mission was to explore the northwest coast of America, investigate the fur trade, and take possession of some suitable harbor north of the Spanish terrortories. The expedition reached the Alaska coast in the vicinity of Yakutat on the 24th of June 1786. The *Boussole* and the *Astrolabe* entered Lituya Bay and La Pérouse took possession in the name of France, believing it a suitable location for a trading post to rival the Hudsons Bay Company. On July 13, three boats under the command of Lieutenant d'Escures left to make soundings in this bay. La Pérouse gave him written instructions, chief of which was not to approach the channel leading into the bay before the sea became slack, because the entrance was blocked by a dangerous bar where breakers formed when the tide was flowing. The boats left at six o'clock in the morning. At ten o'clock, La Pérouse was astonished to see Lietuenant Boutin bringing back the *Boussole's* boat. Boutin related that d'Escures, thought he was still far from the channel, when his boat was suddenly seized by the current. Despite the efforts of his oarsmen to pull the boat to safety, the craft and all who were in it were engulfed. Swept along as he followed his commander into the midst of the breakers which were rushing into the channel at a rapid rate of speed, Lieutenant Boutin skillfully turned his boat's stern into the waves. In this way, by yielding to the waves which struck it, the boat avoided being swamped but was nevertheless swept out backwards by the tide. Presently he saw the breakers in front of his boat and found himself on the high sea. He was continuously forced back by the tide, and he went through the anguish of seeing his unfortunate fellow countrymen perish while he was unable to bring them any help. More bad news followed as the *Astrolabe's* longboat shared the same tragic fate of the Boussole's boat and a total of 21 men lost their lives. In their memory La Pérouse erected a wooden monument on the south point of the island in the bay. It reads:

TWENTY-ONE BRAVE SAILORS
PERISHED AT THE ENTRANCE TO THIS HARBOR:
WHOSOEVER YOU MAY BE,
MINGLE YOU TEARS WITH OURS.

OTHER FREAK WAVES

Tidal races, wind–current interactions, and random reinforcements of wave trains are three other types of wave action.

A tidal race is a region of rough water caused by the current at maximum ebb or flood tide. A race can take the form of severe waves like the rapids in a river, or a whirlpool eddy, and in the extreme can become a waterfall. The latter is usually marked on charts as "overfalls." Overfalls occur most often where an estuary discharges through a narrow gap and over a bar or submerged reef during the ebb although it can occur on a flood tide. Some tidal races have become infamous in history and mythology, such as the one between Italy and Sicily in the Straits of Messina. On the Italian side is the rock called Scylla named for a beautiful nymph, and on the Sicilian side is a whirlpool called Charybdis after a woman in Greek mythology who stole the oxen of Hercules. Part of the hazard of the Messina race is that a portion passes over a shoal area, producing overfalls. Another infamous race is the Maelstrom off the west coast of Norway. Although known in myth as a whirlpool sucking ships to their doom, this tidal race is a confluence of a strong ebb tide with a strong coastal current, creating wildly confused seas with numerous eddies, which can be fatal to small craft.

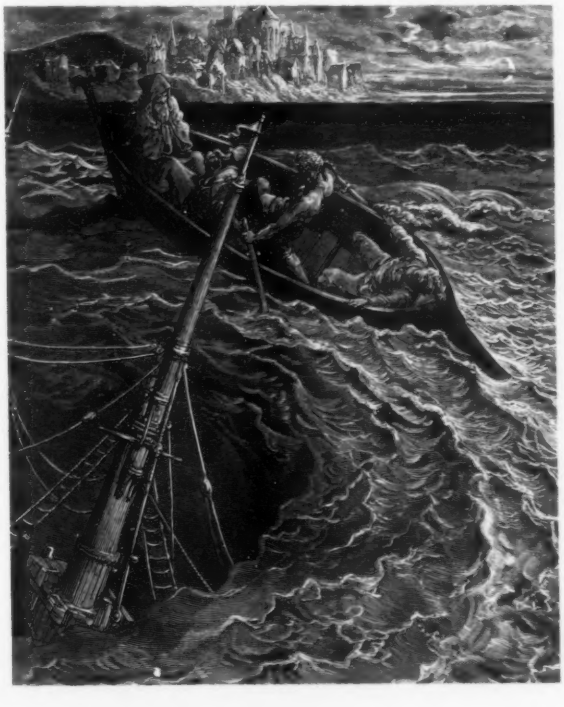
The best documented example of wind–current reaction is covered in this citation from the *Africa Pilot*, describing the freak waves of the Agulhas Current which broke the back of a 28,000–ton ship and tore the bows off at least two supertankers:

...These abnormal waves, which may attain a height of 65 feet (19.8 meters) or more, instead of having the normal sinusoidal wave–form have a very steepfronted leading edge preceded by a very deep trough; caused by a combination of sea and swell waves moving in a north–easterly direction against the Agulhas current; a ship steaming in a southwesterly direction will find her bows still dropping into the trough with increasing momentum when she encounters the steep–fronted face of the oncoming wave, which she steams straight into, the wave eventually breaking over the fore part of the ship with devastating force....

This particular circumstance of a steep downsloped trough leading to a vertical wall of water can also be found in the Straits of Florida, although to a much lesser degree, whenever the local winds are strong from the northeast or east and set up a wave system counter to the Gulf Stream.

Another freak wave is caused by the random reinforcement of wave trains. Whenever two or more swell systems of different wavelengths intersect, the resulting waves are formed by the summation of the instantaneous values of each of the wave trains at a given point. This results in both destructive and constructive interferences. Should all of the trains add constructively at a given point, the resulting instantaneous wave height can be truly awesome. Since the winds blow in toward the eye of the tropical cyclone from all directions of the compass, many wave trains are generated. Most of them intersect within the center of the storm and provide many opportunities for constructive interference. This accounts for the occasional 65– to 85–foot wave encountered in a typhoon or hurricane.

Although referred to as "freak" waves, none of these waves are truly rare. However, they tend to be localized in occurrence or in effect, and mariners will have few opportunities to become familiar with them unless they deliberately seek them out, or through mischance happen to be in the wrong place at the right time.



From the Rime of the Ancient Mariner by Samuel Taylor Coleridge comes Gustave Doré's depiction of a whirlpool. As the ship sinks, the Ancient Mariner is saved by the Pilot's boat:

Upon the whirl where sank the ship, The boat spun round and round. And all was still, save the the hill was telling of the sound.

A version of this article originally appeared as a technical note entitled Solitons, Tidal Bores, Tsunamis and Other Freak Waves in the **MTS Journal**, Vol. 21, No. 4.

High Waves in the Agulhas Current

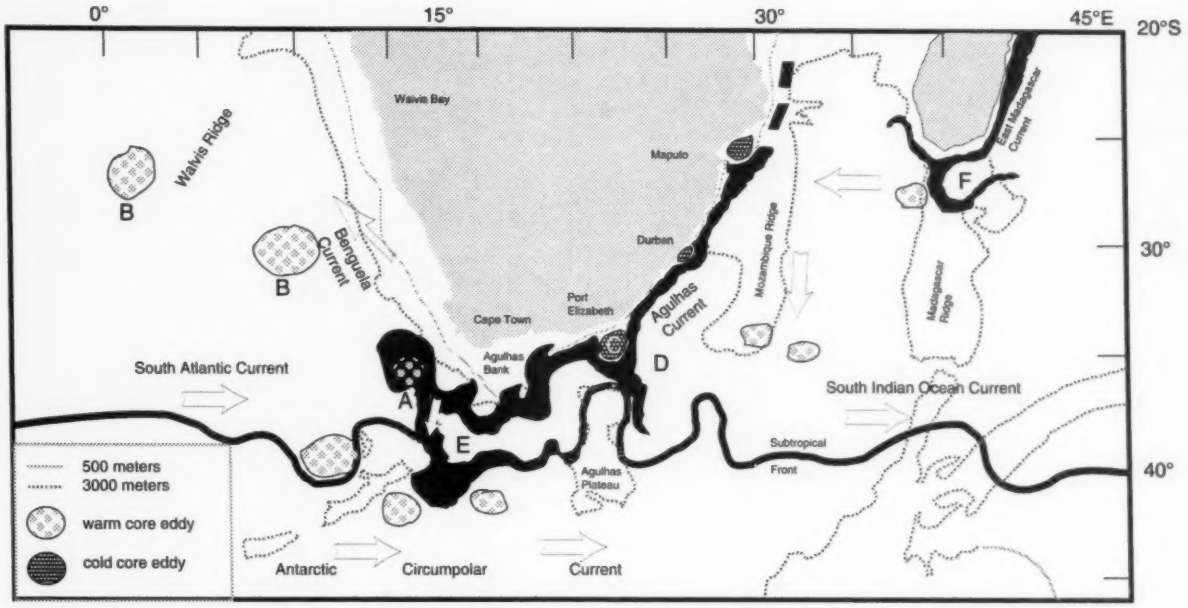
F.A. Shillington and E.H. Schumann

The east coast of South Africa has long been recognized as a region where exceptionally high waves can occur. Possibly the most famous shipping disaster occurred in July 1990 when the ***Waratah*** sailing from Durban to Cape Town was lost without a trace. Since that time there has been a regular succession of shipping casualties. Many articles have been written warning of the dangers–including a number in the *Mariners Weather Log*– but the casualty list continues to climb. Is progress is being made in understanding the phenomenon and can this knowledge be applied in practice?

Experimental results and theoretical formulations have shown that the source of the energy of these high waves lies in a wave and current interaction. For an increase in wave height, the waves and currents must oppose each other, and in the South African case it is the Agulhas Current which flows into waves generated by southwesterly winds, both locally and to the south of the continent. The fact that the Agulhas Current is one of world's major current systems, with speeds of up to 5 knots commonly recorded, means that the resulting waves can be exceptionally high. It also means that a knowledge of the path and speed of the Agulhas Current itself will greatly help in understanding the occurrence of such high waves.

The high speed core of the current flows close to the coast and is guided by the edge of the very narrow continental shelf (at Port St. Johns the inner boundary of the Agulhas Current is usually only 10 kilometers or 5.4 nautical miles offshore). Wave measurements made from a research ship north of Durban in the early 1970s showed that wave energy almost doubled as the ship moved into the current. This enhancement of the wave heights was found to obey a wave/current interaction principle derived by Professor Michael Longuet-Higgins at Cambridge University. Later, Professor John Mallory at the University of Cape Town, reported in 1974 on a number of wave-related shipping disasters along the eastern seaboard of southern Africa. One of these included the sinking of the ***World Glory,*** which was broken in two by "abnormally high waves." In 1976, the *New Scientist* carried a story about the "episodic" high waves in the Agulhas Current, an explanation that later was found to be fallacious.

Hopes of solving the details of the wave cur-

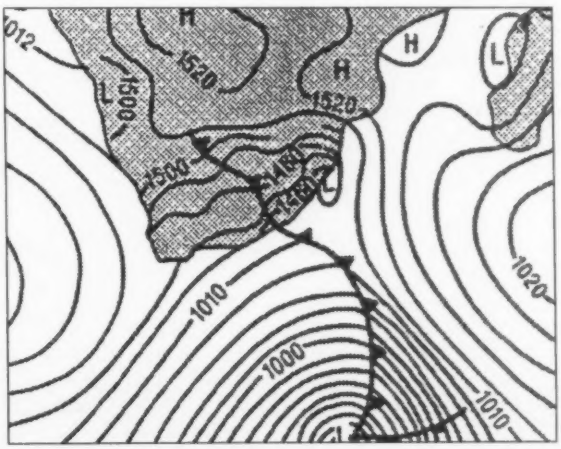


This stylized representation of the Agulhas Current system shows the following circulation features: (A) Agulhas ring shed from the Agulhas Retroflection; (B) Agulhas eddies moving into the southeast Atlantic Ocean; (C, in white) Natal Pulse forcing the Agulhas Current offshore; (D) Early retroflection of the Agulhas Current; (E) Agulhas Current retroflection loop; (F) East Madagascar Current retroflection loop.

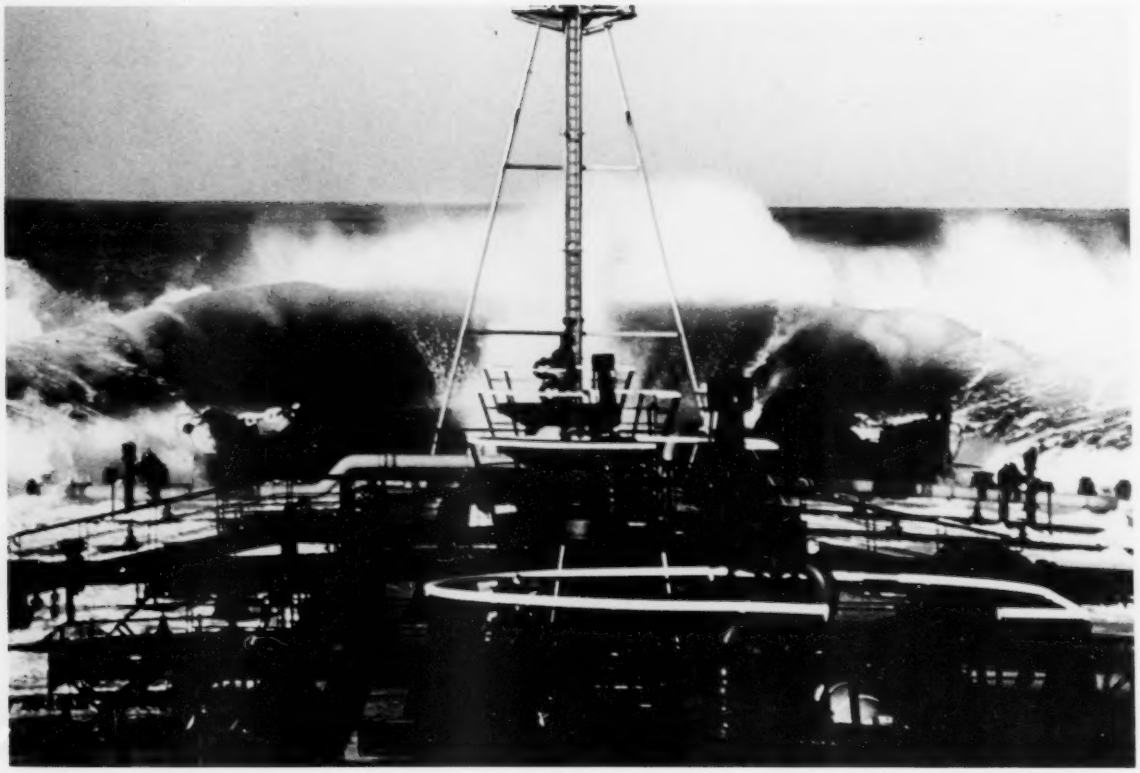
On the preceeding page the Honourable East India Companys iron war steamer ***Nemesis*** *is shown scudding before a heavy gale off the Cape of Good Hope on its passage from England to China. The 165-foot, 660-ton vessel was built in 1840, and was the first iron steam vessel to pass the Cape. Because of rough seas, the* ***Nemesis*** *had to put in at Delagoa Bay for refitting. The artist was H. J. Leathem and the painting was engraved by R. G. Reeve. The plate was first published on October 26, 1841–more than 150 years ago. The print was provided through the courtesy of* ***Maritime Museum****, Newport News, Virginia.*

rent problem in the area were raised when a special Synthetic Aperture Radar instrument (SIR-B) was flown on the Space Shuttle in October 1984, with one of its specific objectives to measure waves in the Agulhas Current. Unfortunately, the shuttle experienced power problems and only a few scans were made in the current area. In addition to the onboard problems, wave heights in the area were small during the week long mission. Despite these difficulties, it was shown by Dr. David Irvine, then at the Johns Hopkins Applied Physics Laboratory, MD, that most of the wave energy concentration was found at the inner boundary of the Agulhas Current (near East London on this occasion). These observations from space pointed to an explanation of high waves that must also include the refraction of the waves by the current and the subsequent build up of energy due to the horizontal velocity shear.

More recent satellites have carried sensors that have been capable of measuring significant wave height on a regular basis, and Dr. Marten Grundlingh of the South African CSIR has used data from the GEOSAT altimeter to statistically analyze wave conditions in the southwest Indian Ocean. He found some enhancement in the Aghulhas Current region, emphasizing the fact even under calm conditions waves can



Frank A. Shillington is an Associate Professor in the Department of Oceanography, University of Cape Town, Rondebosch, South Africa. Eckhart H. Schumann is at the Institute of Coastal Studies, University of Port Elizabeth, P.O. Box 1600, Port Elizabeth, South Africa.



Extremely high waves are encountered by the ***Esso Nederland*** *in the Agulhas Current off Port St. Johns in 1978. The absence of wind is most noticeable, in fact the sun is shining, but the swell was running high at the time. Photograph courtesy of L. Wolhuter.*

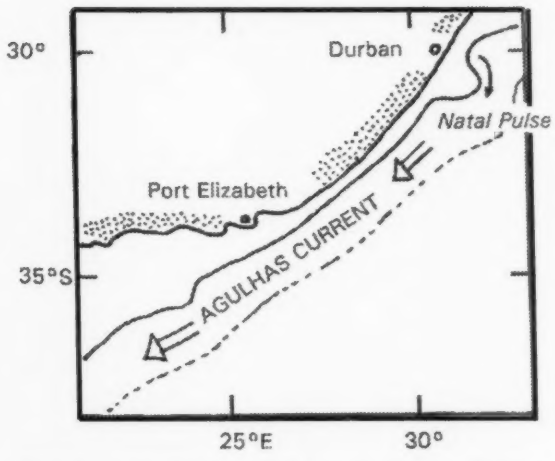
be expected to be enhanced in the current.

Wave Generation

The steady progression, from west to east, of extra-tropical cyclones and their attendant cold fronts is most important for the generation of high waves from south and west of South Africa. These storms have winds that back through west to the southwest and can generate high waves from large fetches. The storms typically move at about 20 to 25 knots to the east, and on occasion their paths curve up along the eastern seaboard. This is the type of synoptic weather system (page 25) that is most likely to generate high waves propagating northeastwards against Aghulhas Current. Swell waves, possibly generated days earlier in the vast reaches of the Southern Ocean, can also reach the Aghulhas Current area, leading to high waves not associated with any local wind. A further compounding factor is the instability of the marine boundary layer over the warm Aghulhas Current, and Dr. Mark Jury (Department of Oceanography, University of Cape Town) has measured spectacular increases in wind speed from flights when flying outwards over the Aghulhas Current. These enhanced winds will cause an additional amplification of wave growth leading to rougher conditions in the current.

Aghulhas Current

Modern technology, in particular satellite imagery, has been very important in recent years in elucidating details of the Agulhas Current structure. The fact that the current is warm relative to adjacent waters makes it easy to identify the current and its boundaries on NOAA infrared sea surface temperature images. Contrary to earlier beliefs, the inner boundary of the current is not straight and does not follow the 200-meter isobath or shelf break exactly. On occasion, as far upstream as Durban, an offshore meander several hundred kilometers diameter can form in the inshore boundary of the Agulhas Current and then slowly propagate downstream as a solitary wave-like pulse. This feature has been named the "Natal Pulse" by Professor Johann Lutjeharms (University of Cape Town), after its place of origin off the South African

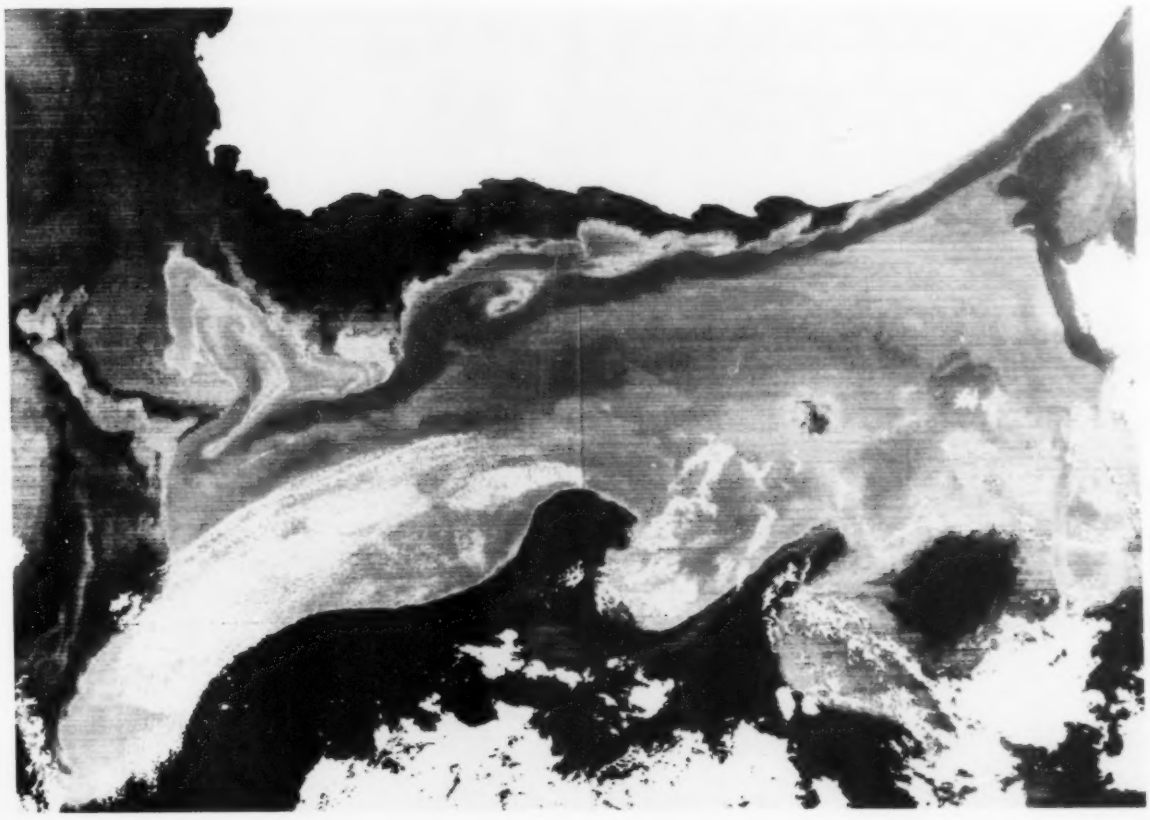


Above is a sketch of the Natal Pulse which meanders in the Agulhas Current boundary.

Below, this NOAA satellite view of the Agulhas Current was taken in 1979. The grey shading represents differences in sea surface temperatures and dramatically highlights the shape of the current and its various pertubations. Photograph courtesy of O. G. Malan.

province of Natal (left). This cyclonic (clockwise in the Southern Hemisphere) meander of the Aghulhas Current moves at about 20 kilometers per day to the southwest. Other smaller scale waviness of the inshore edge of the current is almost always visible on NOAA infrared imagery of the region. These scallops or perturbations have also been shown to move southward at speeds of 20 to 50 kilometers per day and the amplitude (i.e. the cross-current size) increases as they move downstream.

One may ask what these perturbations or kinks in the inner boundary of the Agulhas Current have to do with the occurrence of higher than usual waves? The answer lies in the fact that if strong southwesterly winds are generating large waves that are propagating northeastward against the current, there will be an enhanced wave-current interaction at the wavy boundary. This will be caused by the increased horizontal current shear that is present in these areas, where the wave field is refracted by the current and waves build up in an analogous fashion to wave refraction by the sloping sea bottom near the beach. For a horizontally non-uniform current, the strongest effect of wave refraction is at the inner boundary. This increase in wave energy can be calculated theoretically



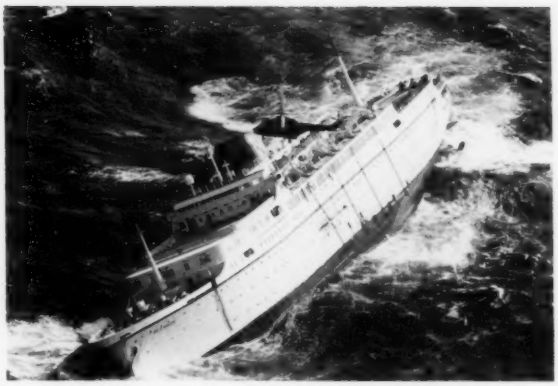
as long as the horizontal current speed and direction, and the wave height and directions are known. Usually all of this essential information is not available, so one has to make estimated or use past data to construct a likely scenario.

Another area of extreme current variability is at the Agulhas Current Retroflection region south of Africa, where large, warm anticyclonic eddies can "bud off." While the nature of these eddy currents is not well known, there is a strong air–sea interaction in this region and a subsequent rapid development of storms and a strengthening of the winds similar to the effects found in Mexico.

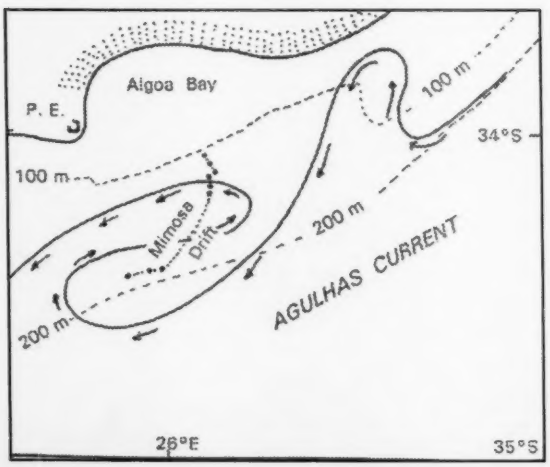
Prediction & Measurement of High Waves

Large destructive waves were again evident in August 1991 when the cruise liner ***Oceanos*** sank in an area off East London. During the storm, the 357,000 dwt Norwegian oil tanker ***Mimosa*** had her rudder badly damaged while in the Agulhas Current less than 20 miles off Port Elizabeth. With no possibility of steerage, the tanker was left to the mercy of the Agulhas Current. Conventional wisdom suggested that she would have drifted in a southwesterly direction past Port Elizabeth. However, over the next few days the ***Mimosa*** reversed her direction of drift and was nearly forced ashore in Algoa Bay (below). Only the prompt action of salvers Pentow Marine, averted what would have been a national disaster. The drift of the ***Mimosa*** was mainly due to the currents associated with the "wavy" nature of the edge of the Agulhas Current at the time and emphasizes the variability of the region and the difficulty of forecasts lacking on–site information.

It is anticipated that once the individual current and meteorological measurements become routinely available, it should be possible to model wave–current interaction and refraction effects due to the Current more accurately and thus improve the forecast of high wave conditions in areas traditionally beset with a heavy wind and wave environment. Passive thermal infrared satellite remote sensing has given insight into the nature of the Agulhas Current boundaries when there are no clouds present, but active microwave measurements from satellites that are able to penetrate cloud and reveal the sea surface roughness hold the best promise for measurements in the Agulhas Current. From maps of sea surface roughness, it is now possible to obtain estimates of wind speed and when these radar measurements are detailed enough, the actual average wave heights can be estimated. Preliminary results for early August 1991 from the European satellite ERS 1 have revealed the character of the extremely severe wind and wave conditions in the Agulhas Current at the time the ***Oceanos*** sank.



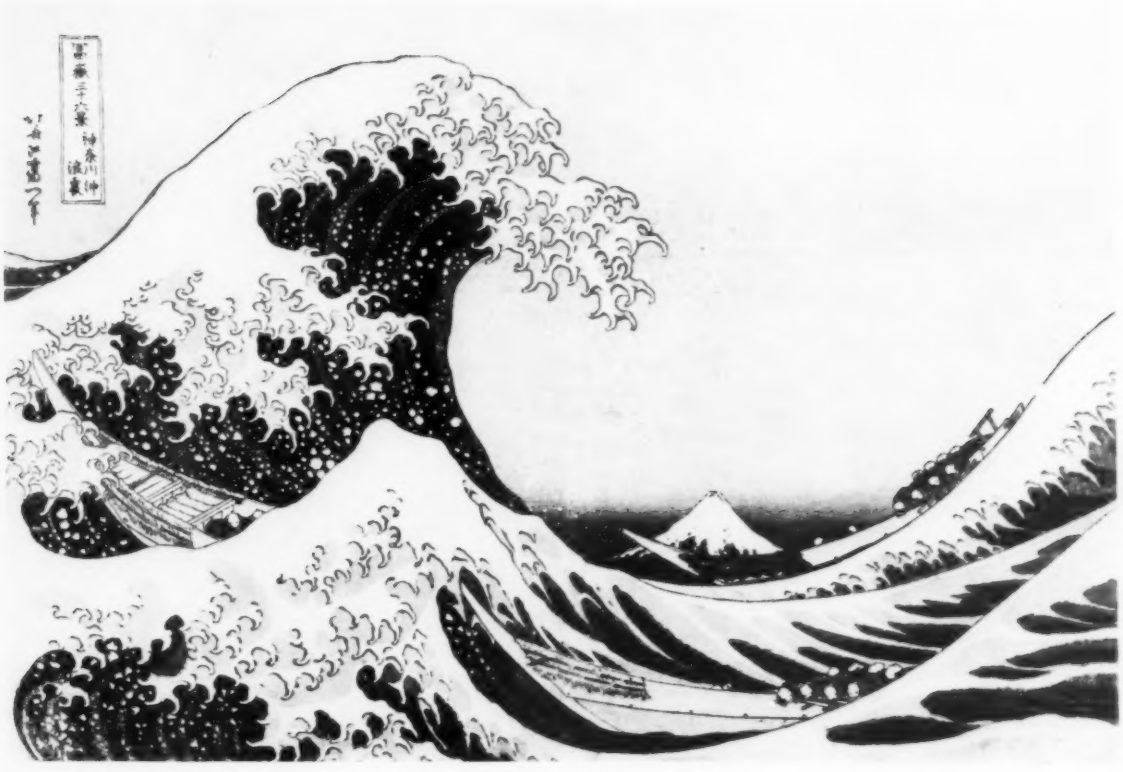
*The **Oceanos** (above) fell victim to the waves off South Africa in August of 1991. Photograph courtesy of the South African Embassy. The **Mimosa** was caught in the same storm and with a badly damagd rudder was moved by the Agulhas Current (below).*



With the high volume of shipping making use of the fast Agulhas Current to speed up the passage around the southern tip of Africa, there have been a large number of reports of encounters with freak or giant waves. The advent of satellite infrared remote sensing of the Agulhas Current boundaries, and satellite microwave sensing of the sea surface, is making it feasible to obtain measurements of wave–current enhancement in near real time. Further advances in the understanding of how waves are generated by the wind, better ocean wind measurements, and routine wave height prediction by global third generation wave forecasting models should begin to improve forecasts of high waves in this area so dangerous to shipping.

A Tsunami is Coming!

Michael J. Mooney



As usual it was the coastal residents who were hit—this time mostly fishermen and their families along hundreds of miles of Nicaragua's Pacific coast. From Corinto in the north to Juan del Sur near the Costa Rican border, 20- to 30-foot tsunami waves stormed ashore.

The 7.1 Richter seaquake struck too near land—just 35 miles offshore—for adequate warnings to be issued in time. A few coastal residents near higher ground escaped unscathed to tell of the disaster. In all some 168 lives were washed away including babies wrenched from their mother's arms and adults found clinging in death to uprooted trees. Another 489 persons were injured and over 13,000 left homeless by the rampaging tsunami. But the Nicaraguan incident pales compared to what took place along Japan's Sanriku coast on Friday evening, June 26, 1896.

On that night, the Shinto festival of *Sanno-Sai* was being held and joyous throngs zigzagged through village streets in merry, noisy processions. The celebrations continued unabated as the heady mixture of sake and the soft light of dusk imparted a hazy, dreamlike aura. At 7:32 p.m. a violent seaquake 120 miles to the east jolted the 32,000-foot floor of the Pacific's Tuscarora Deep, a known source of seismic convulsions. Yet only a minor tremor rippled along the coast as the festivities went on.

Twenty minutes later the sea slowly receded from the shore, quietly passing beyond the farthest withdrawal line of low tide. An ominous quiet

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Michael J. Mooney is a free-lance science writer whose work has appeared in many publications including *Oceans, Popular Mechanics, Ocean Navigator,* and *Science Digest.* Several of his pieces have also appeared in a wonderful book entitled **The Ocean Almanac** by Robert Hendrickson, published by Doubleday.

U.S. Department of Interior

The famous Japanese print on page 29 was produced from a woodcut from The Thirty-Six Views of Fuji *(1823- 29). It was provided by New York's Metropolitan Museum of Art, Henry L. Phillips Collection of Henry L. Phillips, 1939 (JP 2972). Above is an aerial view of Valdez, AK showing the inundation along the coastline, where property damage was estimated at $12 million.*

descended over the surf-silenced coast, but no one paid it any mind. The oblivious revelers had ignored nature's unmistakable warning of an impending tsunami.

It came first as a far-off whisper. The whisper became a hiss, then a rush, growing louder by the second until it reached a watery crescendo. Heads snapped seaward—too late—to behold certain death as an enormous foam-crested wave 110 feet high loomed above them. There was no escape.

Millions of tons of seething water engulfed the coast for hundreds of miles, obliterating scores of villages and decimating entire populations. The surrounding countryside was scarred and ravaged for hundreds of yards inland.

Earlier that evening local fishermen put out to sea for their nightly harvest. Twenty miles off shore, the incoming waves passed unnoticed beneath their keels. On returning home next morning, they beheld a staggering sight—a vast carpet of debris and bodies floating just offshore. On land they found desolation and destruction. Over 27,000 lives were swept away with more than 10,600 dwellings destroyed. Even the Japanese, who have known over 2000 major natural disasters in the last millennium, stood in awe at this consummate stroke of nature.

What are these surging juggernauts that rank among the most terrifying natural phenomena? They are often misnamed "tidal waves" though they have nothing to do with lunar gravitation. The Japanese "tsunami" (tsoo-NAH-mee) or "great wave in harbor" has gained acceptance.

Waves are vibrations or oscillations of disturbances transmitted from one part of a body of water to another. Drop a pebble into a pool and a series of concentric mini-waves radiate outward until they dissipate or strike an obstacle. Tsunamis travel in the same way and can be generated by a severe undersea earthquake (or seaquake), a massive submarine avalanche, or an explosive volcanic explosion.

A severe quake can trigger a tsunami when the seabed suddenly ruptures to cause the great overriding column of water to oscillate violently in seeking its original level. These oscillations radiate outward in all directions as the dreaded waves called tsunamis.

The second cause is a massive submarine avalanche. Giant slides can occur when a nearby earthquake weakens a sizeable segment of unstable sea-slope material. Vertical oscillations again disturb a large enough column of water and cause a tsunami.

The third cause of these great waves is the rarest but most fearsome: the explosive volcanic eruption, which accounted for perhaps the greatest tsunamis of all time— the cataclysmic explosions at Thera (1500-1400 B.C.) in the eastern Mediterranean and Krakatoa (1883) in Indonesia.

Tsunamis can occur anywhere in the world but strike most often along the Pacific Ocean's "rim of fire" of active volcanoes that stretch from Alaska across to Japan, down through the Philippines and Indonesia, the South Pacific islands, and over to South America.

Unlike wind-generated waves, tsunamis are true gravity waves with exceptionally long length and period. More than 150 miles can separate two successive crests that are just a few feet high. It's not surprising these waves go unnoticed by those offshore and are totally undetectable from the air.

Tsunami waves attain astounding speeds while transiting an ocean. Lagrange's Law explains how a tsunami's forward velocity equals the square root of the product of the acceleration of gravity and the depth of the water in feet. In other words, a tsunami passing

U.S. Department of Interior

The tsunami of March 27, 1964 devastated Seward, AK. This is a view of the north end of Ressurection Bay which was taken in April of that year. The earthquake actually struck the northern shore of Prince William Sound, AK at 0336 UTC and was the most severe ever recorded for North America. In Alaska it was still Good Friday afternoon and the earthquake became known by this name.

through water 20,000 feet deep will race along at 545 miles per hour. When the tsunami approaches land the sea floor shelves up and the great waves "feel the bottom." This friction slows their forward momentum and kinetic energy is transferred into the fearsome vertical specters that terrorized coastal inhabitants through the ages.

Tsunamis come in all sizes: from lapping wavelets just inches high to hurtling mountains of raging water more than 100 feet high. When Krakatoa blew its top in 1883, monster waves up to 135 feet high ravaged nearby coastal areas in all directions. Other Krakatoa waves travelled halfway around the world to register mere inches in the English Channel.

Tsunami height is determined by the original disturbance, its distance, and local offshore topography. The tsunami that struck Cape Lopatka on eastern Siberia's Kamchatka Peninsula in 1737 measured a colossal 210 feet above sea level.

The tsunami is rarely a single monster wave but a "train" of successive surges 15 minutes to an hour or more apart—and any of these waves can pulverize a coastline. The first sign of an approaching tsunami train is often the trough between successive waves—that chilling withdrawal of sea from shore. How a coastline is shaped plays an important part in defining a tsunami's intensity. Deep water extending close inshore inhibits height-producing bottom friction and the impact is minimal.

Offshore coral reefs can act as natural breakwaters and "damp down" an incoming tsunami. But if the bottom contour shelves gradually upward, incoming tsunami waves build to frightening proportions. The worst possible configuration is the V-shaped coastal inlet where a tsunami's force is concentrated and funneled into a watery colossus of devastating proportions. The Hawaiian port of Hilo is such a place.

How far across an ocean can a tsunami travel and retain its potential for destruction? Depending on the original disturbance, tsunamis can travel many thousands of miles before finally dissipating. The world's longest tsunami originated off Chile and fanned out more than 12,000 miles across the Pacific—nearly half the

U. S. Navy

An earthquake on the coast of Chile on May 22, 1960 produced a tsunami which devastated the Waiakea area of Hilo, HI. Bent parking meters show the direction of the tsunami.

world's circumference—to the distant shores of eastern Siberia. Long range tsunamis can even bounce off continental barriers and reflect back across the ocean—like a huge seiche.

On April 1, 1946 a surprise April Fool's tsunami train bushwhacked the Hawaiian Islands, taking more than 160 lives. This time the culprit was a combined submarine seaquake and avalanche off the Aleutians far to the north.

This proved to be the turning point in the long struggle against the dreaded tsunami. Reacting to this proverbial last straw, a group of oceanographers, who happened to be on the scene, decided something had to be done, to forewarn coastal populations of incoming tsunamis. They compared the epicenter's location and the time it took for the waves to reach Hawaii and suggested that similar waves could be predicted if such data were available. Thus was born the Seismic Sea Wave Warning System (SSWWS). Edwin P. Weigel described how SSWWS worked:

Briefly stated, the warning system is based on, first, the detection and pinpointing of an earthquake big enough to cause a tsunami, and second, the identification by tide gauges of ocean waves generated by that earthquake. A "tsunami watch" is issued when the proper category earthquake is detected. A "tsunami warning" is issued when the presence of seismic sea waves is confirmed. Included in the warning are quite precise forecasts of arrival times for the first wave of the tsunami at populated points in and around the Pacific basin.

This system depended on reliable, ocean-wide, seismic and tidal recording equipment that permitted the rapid issuance of accurate warnings. A special "travel time" chart was devised with concentric circles centered on Honolulu, each circle depicting an hour's travel time by a given tsunami based on enroute seabed topography. Similar charts were developed for other tsunami-prone population centers.

Four years later, on Good Friday 1964, the Great Alaskan Earthquake spawned killer tsunami trains that ravaged nearby coastal areas before effective warnings could be sent. Out of this disaster came the local Alaskan Regional Tsunami Warning System, headquartered outside Anchorage for near-immediate response to Alaskan tsunami emergencies. Other tsunami-prone areas have developed similar local systems.

In 1969, SSWWS became the Tsunami Warning System (TWS) and new ways were sought to reduce the number of sneak tsunamis that sometimes slipped through the ranks of existing monitors. Another priority was to further reduce the warning response times for all tsunamis. Additional reporting and recording stations were installed and augmented by a system of Geostationary Operational Environmental Satellites (GOES). In recent years a low-cost local set-up called THRUST was developed for the seismically-sensitive west coast of Chile.

No manmade sea defense exists to physically stop a tsunami. Ambitious plans to sink massive offshore breakwaters and shift vulnerable residential areas to higher ground inland are simply beyond the financial capabilities of most maritime nations.

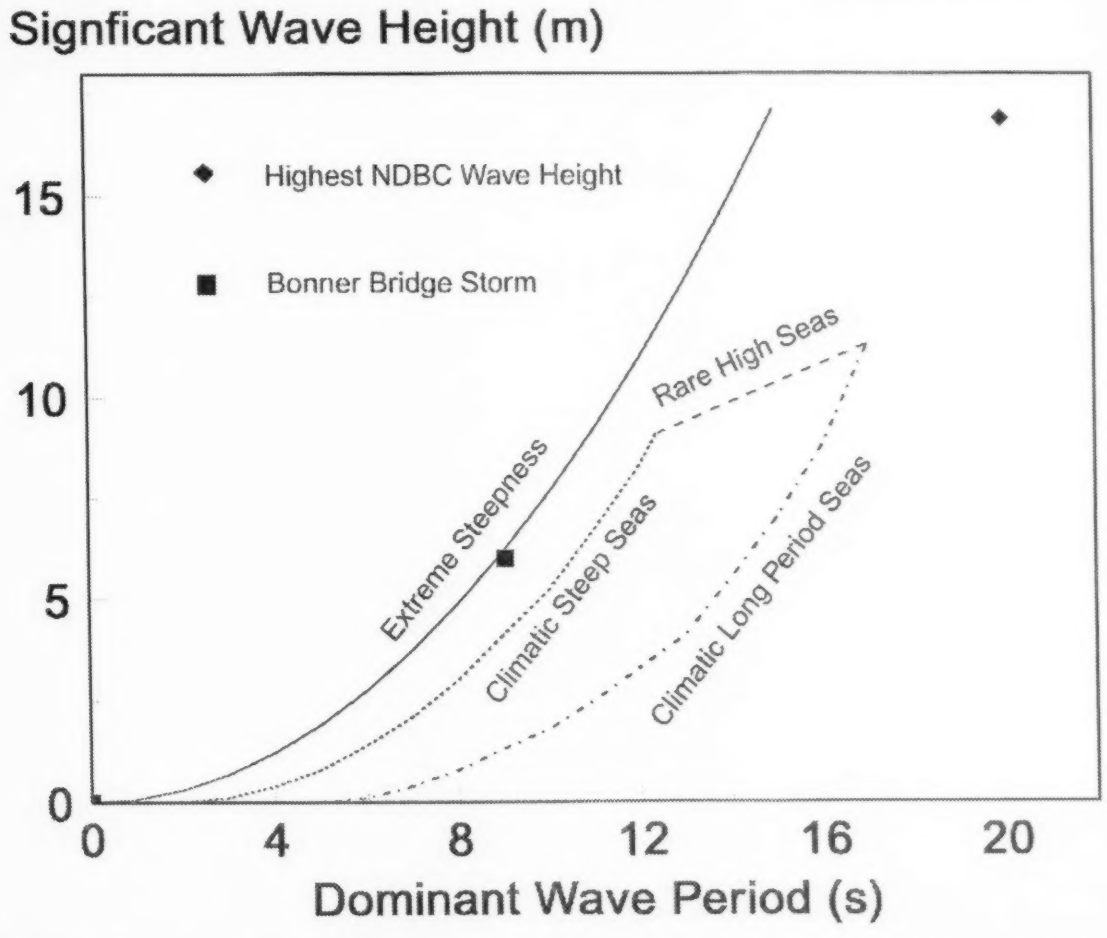
The only foreseeable hope is to reduce tsunami warning times to an absolute minimum and further educate coastal population to the realities of these great waves. Seismic and volcanic convulsions will continue to occur and often do not conform to tidy prediction and probability studies. In recent years, tsunami-prone coastal areas have been increasingly developed and populated with little thought to the grievous loss of life and property that will occur when the big waves come— as they inevitably must.

Buoy Wave Extremes

David B. Gilhousen
National Buoy Data Center

The highest wave height ever reported by a National Data Buoy Center (NDBC) station is only 16.9 meters. This seems low since mariners have reported freak waves with heights exceeding 30 meters. Part of the reason lies in an understanding of what is measured. NDBC buoys measure the **significant wave height**, which is the average of the heights of the highest third of the waves. From a statistical standpoint, there's a 5% chance of encountering a 32-meter wave given a 16.9-meter significant wave height measured during a 20 minute sampling period. The entire time series wave record is too long to transmit back to shore via satellite, consequently, exact measurements of extreme wave heights are not available.

A factor that is often over-

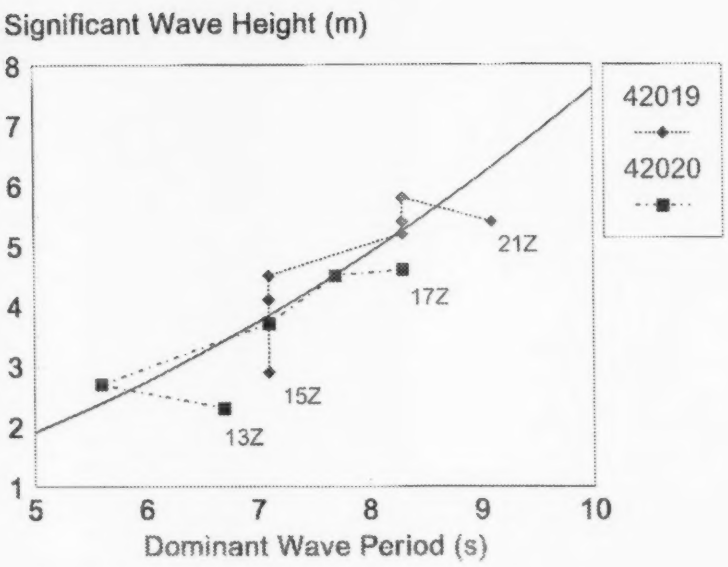


A plot of significant wave height versus dominant wave period containing the curves as determined by Buckley and two extreme NDBC observations. By plotting significant wave heights and dominant wave periods on this chart you can get an estimate of steepness.

looked in describing sea state is **wave steepness**. Civil engineers and naval architects have observed that small vessel capsizing and marine structural damage is caused by waves that are either high or steep. Unfortunately, meteorologists almost exclusively focus on wave heights in marine forecasts. However, you can determine a measure of steepness from NDBC stations by plotting the significant wave height versus dominant wave period.

The chart on page 33 shows a plot of these two parameters along with wave steepness curves determined by William H. Buckley in an article about extreme and climatic wave spectra. He reviewed the entire archive of NDBC data for all stations and Canadian oil rig observations in order to compute wave climatologies. Then, he empirically fit the function that describes steepness from linear wave theory to the steepest events to obtain the curve, $H_{1/3} = 0.00776 g T_p^2$ where $H_{1/3}$ is the significant wave height, g is gravity, and T_p is the dominant wave period. This curve is labeled "Extreme Steepness" in the chart. Most observations lie well to the right of this curve, between the curves labeled "Climatic Steep Seas" and "Climatic Long Period Seas" and below the curve labeled "Rare High Seas."

Also plotted are two NDBC observations taken during winter storms. The observation labeled as "Bonner Bridge Storm" was taken at buoy station 44014 east of Virginia Beach, VA, during this famous October 1990 storm. Because this was a rapidly deepening "bomb," the winds rapidly increased. This creates waves whose height increases relatively faster than the wave length, leading to steep seas. Indeed, the waves approached the extreme steepness curve for this particular storm.



Observations of significant wave height and dominant wave period from 42019 and 42020 on March 12, 1993. The dotted lines connect consecutive hourly observations for each buoy station. The time labels show the first and last observations for each buoy.

On the other hand, the highest significant wave ever reported by NDBC, with relatively long wave lengths, occurred at buoy station 46003 in the northeast Pacific. These waves can cause tremendous damage to shore structures because they carry large amounts of energy.

Of recent interest are some measurements taken in the Western Gulf of Mexico during March 1993's "Storm of the Century." The chart above is an enlarged section of the previous chart showing a time trace of observations transmitted by 42019 and 42020 during the morning of March 12. The storm was rapidly deepening just to the east of these stations. Note that some observations lie to the left of the "Extreme Steepness" curve, and are therefore, probably the steepest waves NDBC has ever measured for these wave heights. They indicate phenomenal wave growth and confirm the presence of strong winds and a rapidly deepening storm. Their steepness also portends the type of widespread maritime calamity that followed. As reported in the last issue of *Mariners Weather Log*, the Coast Guard conducted 111 Search and Rescue efforts from Texas to Appalachee Bay.

In conclusion, a good way to place NDBC wave observations in perspective is to plot them on the first chart. Observations falling to the left of the "Climatic Steep Seas" and above the "Rare High Seas" curve indicate dangerously steep or high wave conditions.

For Further Reading

Buckley, W.H., 1988: Extreme and Climatic Wave Spectra for Use in Structural Design of Ships. *Naval Engineers' Journal*, 100, No. 5, pp. 36-57.

The Treachery of Freak Waves

Captain T. Wilson Cameron, MNI

In 1961, I was a master of a small reefer on a voyage from Dover to Las Palmas. Our passage across the Bay of Biscay in ballast was very stormy—the month was January. When off the northwest coast of Spain, the wind was on our starboard quarter, blowing a moderate gale with a very rough sea. Our Spanish third mate, an excellent and mature officer, fixed our position by bearings of shore lights and reported that we were on the 100-fathom line and stated, "Very dangerous seas are often found around here." I asked him where he had obtained this information from, and he replied that his father and grandfather had often warned him about this area.

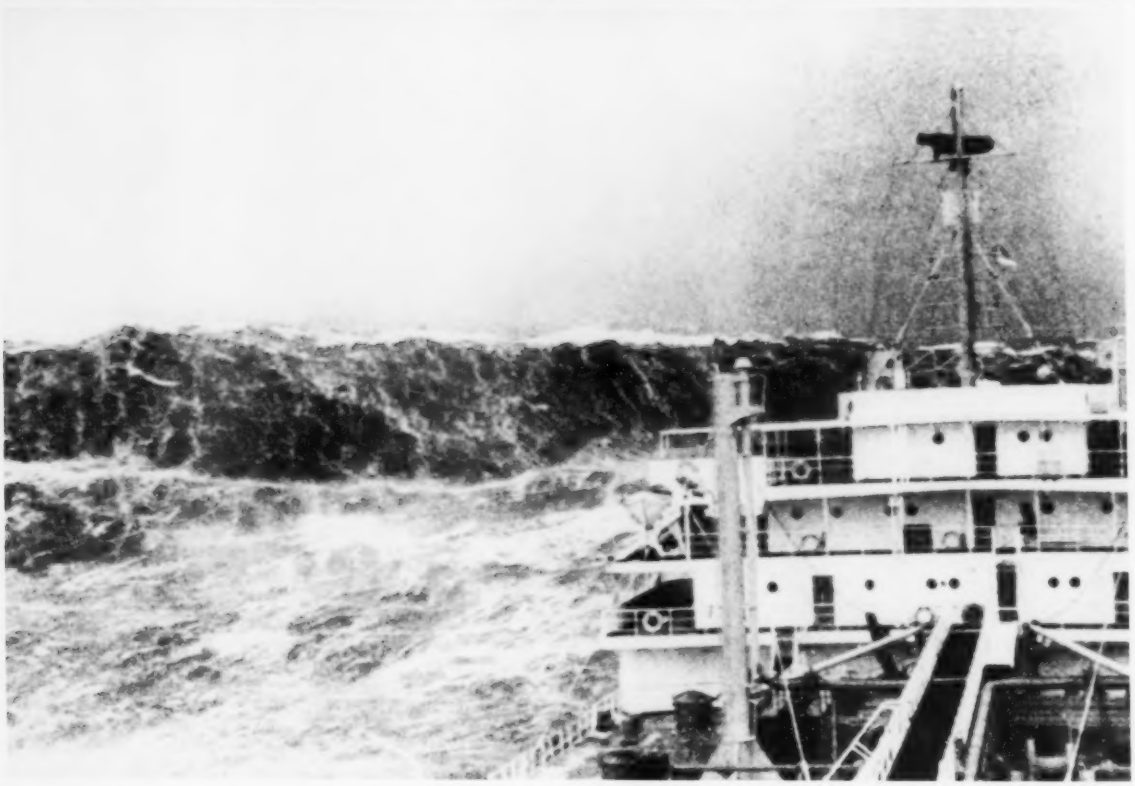
Forthwith we altered course four points to starboard and in an hour or so sea conditions improved considerably, so we were able to resume course for our destination and our voyage was completed without trouble. I have always remembered my Spanish shipmate's advice, and passed the information on to many officers I sailed with afterwards, especially if we were passing the Bay of Biscay.

Several years later I was sailing on this particular voyage as chief officer on a very well-constructed, well-maintained ore carrier from Monrovia to Birkenhead. The vessel was of 156,000 tons dwt, with bridge amidships and engines aft. I noticed one day that our homeward-bound track had been laid off right on the 100-fathom line off the coast of Portugal and Spain. I advised the master of the warning I had received from my Spanish officer and the source of his information, but my captain said he did not believe yarns from third mates and we would keep the course as laid off.

A few days later off the northwest coast of Spain, the wind was north-by-west, force 6 to 7 and the ship was spraying and occasionally shipping water. The weather was not troubling our ship to any extent. The sky was partly cloudy with a full moon in the west. At 0520 hours, the moon was blotted out and all turned dark. I looked to port to see what kind of cloud could obscure the moon so thoroughly, and was amazed—horrified, rather—to discover it was no cloud, but an immense wave approaching on our port beam. It stretched far north and south, had no crest, nor white streaks, and as it neared at quite a speed, I could see its front was nearly vertical. I yelled to the lookout man to come into the wheelhouse as he was on the starboard side of the bridge and could not see the wave.

As near as I could judge, about 80 to 100 yards away the wave started to break, and in another few seconds reached our ship and struck us fair abeam with three distinct separate shocks, sweeping our ship for her full length. Fortunately, the vessel rolled away just before the impact, and this I am sure saved us from even more serious damage. Our MacGregor hatches escaped any injury and sounding around the ship revealed we were not making water. Some of the damaged items were quite extraordinary.

The forecastle head deck was set down about 3 inches and inside 14-inch channel bars which



An unidentified vessel encounters a terrifying "Shoaling" freak wave along the 100–fathom line in the Bay of Biscay. These waves apparently originate off the east coast of North America and travel thousand of miles across the North Atlantic as long wavelength swells. As they approach the rapid rising bottom of the Bay of Biscay, they quickly begin to decrease in wavelength but increase dramatically in height. Fortunately, conditions have to be just right over the North Atlantic in order for these swells to make the long journey– a rare occurrence. Ships encountering these steep–faced, swell–type waves at their peak, have vanished without a trace. –Jerry Nickerson.

formed the deckhead beams were cracked through, 5 inch stanchions were buckled and the wooden shelving supported by 5 by 5 inch timber vertical uprights were almost completely wrecked; many uprights were split top to bottom. Two floodlights bolted to our curved bridge front were swept away, along with their mountings—these were 50 feet above the sea. Heavy steel ladders from the bridge to the main deck were torn from their fastings, spun around on their handrails and rammed up into a nearby alleyway where they stayed jammed against the deckheads.

Despite heavy brass helmets, the glasses were cracked on both gyro repeater and magnetic compasses on the monkey island 70 feet above our waterline. On the after house, heavy permanent awnings made of sturdy corrugated plastic and bolted in position were mostly swept away. There were many strange items of damage, but the ship remained watertight and seaworthy.

The wave was higher than our foremost track—85 feet above the water. As this wave approached from a direction 90 degrees different from the normal sea and wind, which had been northerly for a few days previously, I put its existence down to a submarine earthquake in the mid–Atlantic ridge. Certainly it appeared so much different from the normal wind–generated sea, of which I have seen thousands. There was no crest, nor white streaks, a nearly vertical front and quite a fast approach. Some time after this event, out of curiosity, I calculated the altitude of the moon at the time and found it to be 17°

42'. When daylight came, and I could examine the ship closely, I found that along with other strange damage, our 7-inch thick windlass bedplate had been cracked right through and right across in the way of the spurling pipes. The damage had to be reported to the owners.

Another instance that remined me of the Spanish mate's warning happened in January of 1984. I was reading in a popular Sunday newspaper that an Italian bulk carrier of some 20,000 tons was en route to Genoa from Rotterdam, when about half-way across the Bay of Biscay the master had reported to his owners that all was well. The ship, however, was never heard of again after this. The paper went on to say that the previous year, a ship of the same company, of the same tonnage and on the same voyage had similarly vanished. This disappearance of two ships puzzled everyone concerned. I wrote the paper telling of my warning and experience on the 100 fathom line off northwest-Spain, and although acknowledged, no paragraph or word of warning was given.

On one Admiralty chart I can remember a little printed warning notice advising one to give the coast a wide berth, as the lights, being high, were often invisible in low cloud conditions. It would be quite natural for a cautious or nervous mariner to steer out for the 100-fathom contour line and use it as a clearing mark, only to encounter a dangerous sea often—I repeat, often—found hereabouts.

In 1963, I was on a voyage from Corpus Christi, Texas to Rotterdam on a 16,000-ton bulk carrier, 6 months old, with everything aft. One evening we had just passed Miami and were endeavoring to stay in the axis of the Gulf Stream. It was a beautiful night, with a light north northeast breeze, rippled sea, almost cloudless and with a full moon shining. I was yarning to the chief engineer in his room when I felt the ship commence to lift forward. I ran to the window and was startled to see an immense white foaming mass close ahead. I made the wheelhouse one flight up in record time and arriving there just as the foaming wave came over the bow. The entire deck was flooded to the gunwales; the sea water lashing about the deck was alive with phosphorescence.

Once the solitary wave passed, the surface of the sea returned to normal—just rippled—and there was no more alarms. The only damage we sustained was a slightly bent ladder, leading up to our after mast house, 400 feet abaft our stem. My chief officer who was of a mathematical turn of mind, calculated that when we were full of sea water on deck to the top of the bulwarks some 3,000 tons of water was aboard.

An intense low had remained stationary for a few days northeast of Cape Hatteras and on the great circle track I intended to follow for the English Channel.

I did wonder later—did the mv ***Sulphur Queen*** encounter such a sea? It was a T2 tanker engaged in carrying liquid sulphur, and on our maiden voyage whilst we were anchored awaiting aberth outside Port Arthur, Texas, it sailed from that port bound for a northern port in the U.S. It vanished without a trace.

In 48 years at sea, naturally, I have encountered many gales in all the oceans of the world, but only twice have I encountered abnormal seas, and these are described here. A few years later I brought a paperback, *The Bermuda Triangle*. In that book I learned that an American passenger ship from Miami to Nassau had on the same night encountered a sudden wave on her port beam, which had caused considerable consternation on board.

I was surprised to read in *Seaways* that someone at a lecture about abnormal waves cast some doubts and disparaging remarks about the subject. That member has been lucky, but King Solomon, a landlubber, had the same trouble. However, he was honest enough to confess it in Proverbs 30:18-19: "Three things are too wonderful for me; four I do not understand: the way of an eagle in the sky, the way of a serpent on a rock, the way of a ship on the high seas, and the way of a man with a maiden."

This terrific article was originally published in our sister magazine The ***Marine Observer*** *back in October 1985. They had received it as part of a feature entitled "Incident Desk" in* ***Seaways*** *January 1985.*

This account confirms the intent of the rest of our special issue. Possible explanations for these horrendous waves can be found in Nickerson's article as well as the article by Shillington and Shumann, which describes the same type of waves that might be encountered in the Gulf Stream. We have in the past covered just such waves. We owe a debt of gratitude to the ***Marine Observer, Seaways,*** *and Captain Cameron for sharing this bit of wisdom with us.*

–ed.

Great Waves at Rock Lighthouses

Elinor De Wire
Mystic Seaport Museum

The seacoast of Britain is surely among the most dangerous in all the world; it is fringed by sinister rocks with equally sinister names–the terrible Lizard, Cape Wrath, precipitous Dubh Artach whose name means "the black one of death," Inchcape with its legendary warning bell, and Wolf Rock where the sea rushes through a blowhole with a demonic howl.

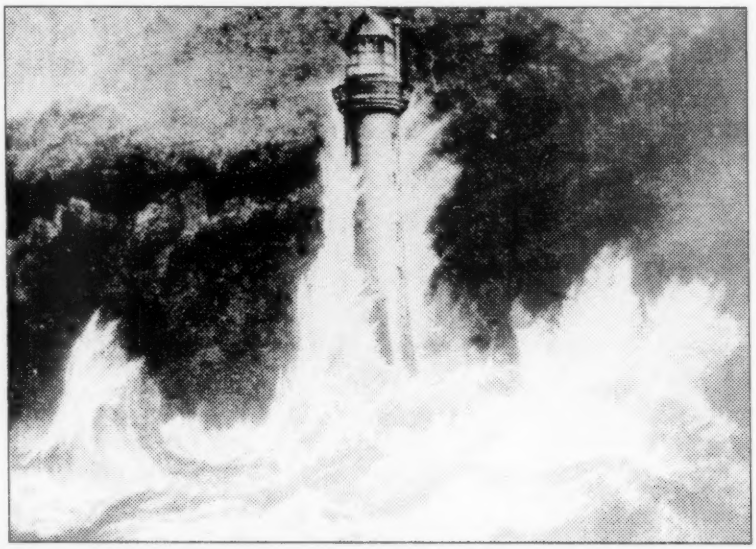
English fogs, converging currents, whirlpools, strong tides, boreal winds, and heavy seas are among the mariner's nightmares here. These have challenged marine engineers too, particularly those who built Britain's magnificent rock lighthouses. Some of the world's tallest and most exposed towers stand watch here. Rising from the rocks like cathedrals, they light the 350-mile English Channel and perilous spots in the North Sea, Irish Sea, St. George's Channel, and the Hebrides.

Engineers learned to build sentinels on these exposed sites by trial and error, often with many lives lost in the process. Some thought they had achieved success only to witness the sea tear down in one night what had taken years to build. Most startling was the incredible size and force of certain waves described here by author Tony Parker:

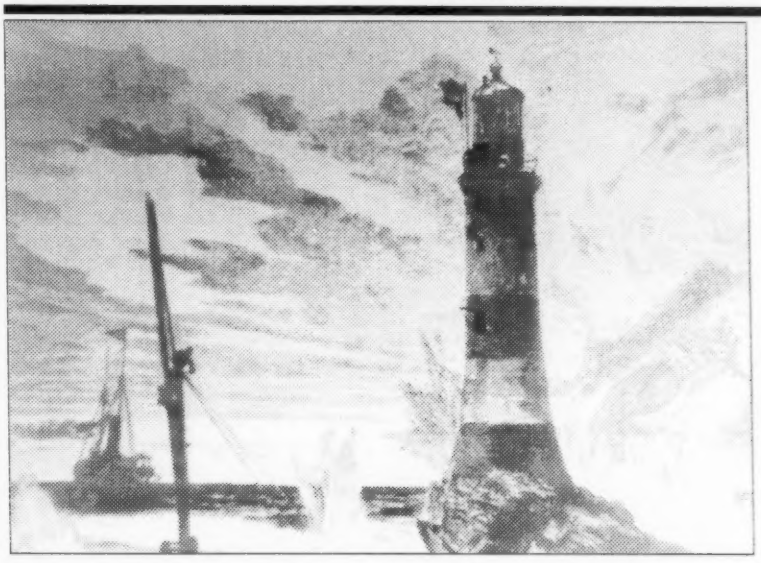
"A distant thud as though someone had swung a gigantic sledgehammer against the base of the tower. The electric lightbulb twitches, the plates on the dresser rattle; coffee slops out of a full cup onto the table. Outside the window a suddenly obliterating surge of creamy white, like a bucket of whitewash thrown against it– the crest of a wave breaking 85 feet above sea level."

Parker wrote about his experience on one of England's rock lighthouses in the 1960s. He spent several weeks living with the keepers, recording life on a dismal stump of masonry miles at sea, and returned to shore red-eyed and frazzled from the incessant din of the waves crashing against the tower. It made him marvel at the mettle of the men who tended such lights, but also of the men who built them.

The most renowned engineers of wave-swept lighthouses were the Stevensons of Scotland. They built the massive stone towers



Waves climb the Bell Rock Lighthouse along the east coast of Scotland, near the town of Arboath. Photograph courtesy of the Northern Lighthouse Board.



The fourth Eddystone Lighthouse during construction of the new light in 1879. A previous lighthouse erected in 1754 fell victim to the splitting of the rock. Photograph courtesy of Trinity House.

that still stand at Bell Rock, Skerryvore, Dunnet Head, Dubh Artach, and other perilous sites. Their most celebrated son, Robert Louis Stevenson, declined a career building lighthouses and took to pen and paper instead, but his view of the world seems to have always passed through the prisms of a lighthouse and was greatly influenced by his family's struggle to mark Scotland's treacherous coast.

Robert Stevenson (Robert Louis' grandfather) was the patriarch of the family and one of the world's most knowledgeable marine engineers. With his son, Thomas, he designed a wave dynamometer to measure the force of waves striking a solid surface. It consisted of a 6-inch diameter plate mounted on a stiff horizontal spring. A rod behind the spring moved each time a wave struck the plate.

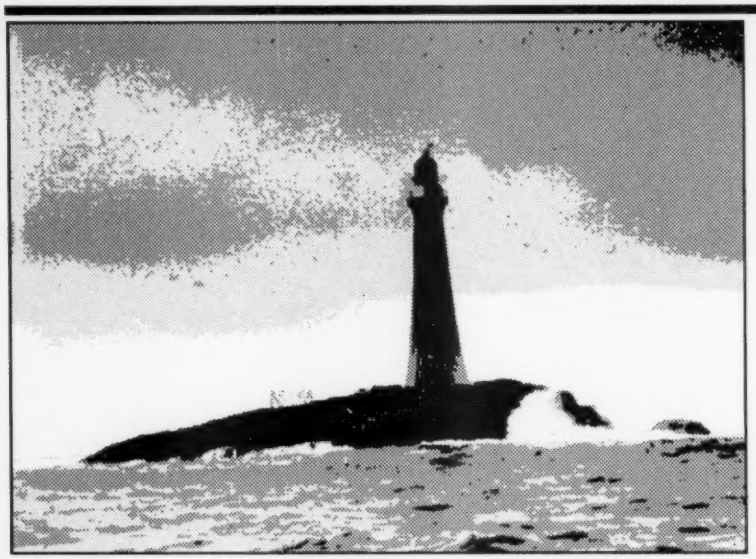
During a winter gale at Skerryvore off the Hebrides, where the Stevensons built their most magnificent lighthouse, wave force was measured at 6,083 pounds per square inch. A century later, a force more than double that was recorded by waves that tore up the stone breakwater at Cherbourg, France. Blocks weighing 7,000 pounds were hurled as far as 60 feet, ominously proving what the Stevensons already knew: The Atlantic could heave 3,000 miles of unbridled anger against the coastlines of Europe.

Logbooks from Britain's rock lighthouses contain incredible accounts of waves, recorded by the keepers who experienced them. Some did not live to tell their stories. This was true of the keepers of the Eddystone Lighthouse in the English Channel, the world's first sea-swept sentinel. Waves easily passed through the lantern of the tower, 40 feet above low water. Still, it was an amazing structure for the year 1698, and its architect, Henry Winstanley taught engineers much about building lighthouses on exposed rocks. In 1699 he strengthened the original tower and swore that nothing would please him more than to be in his lighthouse during the greatest storm.

Unfortunately, he got his wish in November 1703. The great storm on the 26th of the month was likened to a ceaseless tornado. "Trees fell like grass before a great scythe, leaden roofs of churches and cathedrals were rolled up like grey carpets," wrote a contemporary historian. The Eddystone Light stood gallantly for most of the night, then disappeared into the turbid channel.

Subsequent towers on the Eddystone revealed important things engineers had learned. Ornamentation was gone—no fancy finials or embellished windows for waves to grasp—and a flared shape proved best, to cause waves to be thrown back upon themselves. Tower bases were constructed of solid masonry several courses high, and blocks were dovetailed to anchor them more firmly. The idea was to make a rock lighthouse an extension of the rock itself. Titanic waves still came, but the towers stood strong, and the keepers lived to recount their experiences.

The sea had an alarming habit of opening doors at some lighthouses, almost as if waves had fingers that could pick locks and turn knobs. Most times they didn't bother to knock. A keeper at Unst Light in the Shetland Islands in the 1850s saw his door rip off its hinges and disappear into the darkness, never to be recovered. Similarly, in 1840 on a relatively calm night at the Eddystone Light, an unusual wave crawled 50 feet up the tower and blew out a door. The keeper was surprised to find



Dubh Artach Lighthouse lies in the middle of the Firth of Lorne, near the island of Mull, and is sometimes called St. John's Rock. Photograph courtesy of Northern Lighthouse

that the door had survived the initial crush of the wave but had given way in the backdraught due to pneumatic pressure– the heavy and abrupt release of force as the wave withdrew from the door.

During the building of Dunnet Head Lighthouse in 1831 opposite the Orkney Islands, workmen were shocked to find that waves could scale the 300-foot cliff face below the lighthouse. Not only that, but stones of considerable size were tossed upwards like gray beachballs and damaged the tower. If 300 feet of cliff face were no deterrent, what of a 100-foot lighthouse?

During the construction of Dubh Artach Light in 1872 between Skerryvore Light and the island of Colonsay, 14 blocks weighing 10 tons each were torn out by waves 37 feet up on the tower. Robert Louis Stevenson wrote that the waves over this rock in the Hebrides "growled about the outer reef for ever, and ever and again; in the calmest weather, roared and spouted on the rock itself."

David Stevenson, builder of Dubh Artach Light, believed the sea here to be the most violent he had ever witnessed. Investigation showed that the rock lay at the head of an 80-mile long submarine valley which funneled and concentrated the waves hitting Dubh Artach. Stevenson estimated a wave force of 3 tons per square foot in winter gales; hence he opted to make the tower's base solid block to a height of 64 feet.

Concerns about the power of the waves at Dubh Artach were confirmed only a week after the lighthouse went into operation. November seas wrenched a copper lightning conductor off the tower at a height of 92 feet on the lee side. The conductor had been snugly nestled in a channel running down the side of the tower and secured tightly with screws. The waves bent the conductor tube upwards and tore its screws from their sockets.

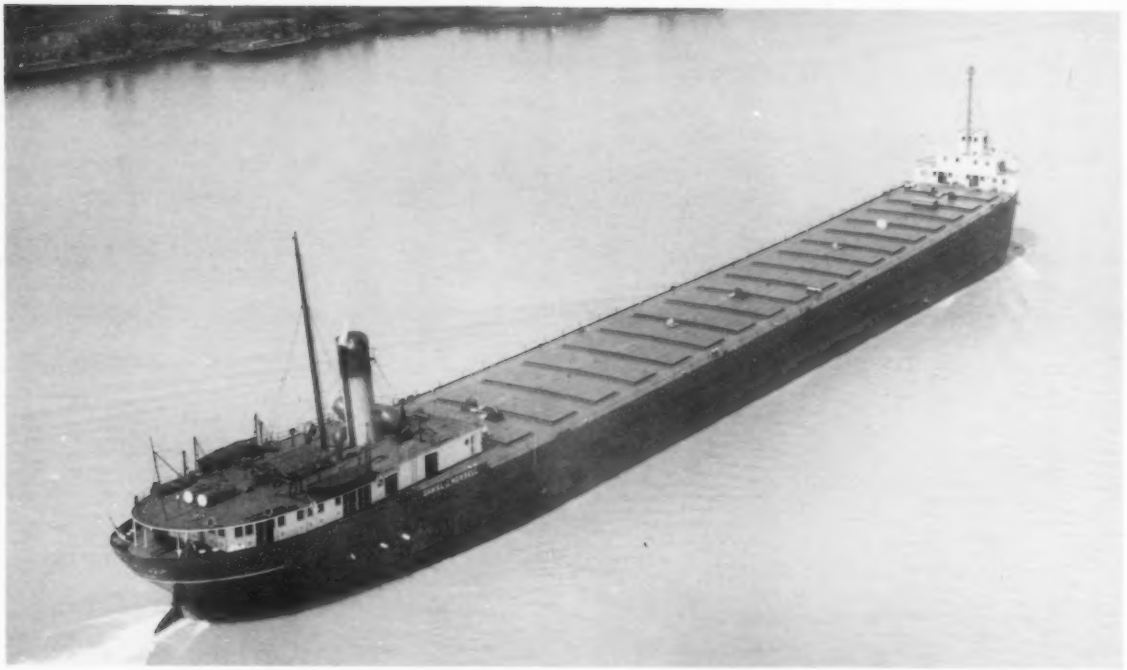
Tale upon tale could be told about the destructiveness of waves and the woes of the rock lightkeepers, but in fairness to the sea, which can give as easily as it takes, a happier ending is in order. It involves the first lighthouse to be built on the Smalls, along the tempestuous coastline of Wales. It was a strange structure for its time, a house and lantern perched on wooden stilts anchored to the sprawling reef 21 miles west of St. Ann's Head.

The year was 1777, and four men were marooned on the Smalls Light: the two keepers, plus two workmen who had come to repair the rickety legs of the tower. The weather deteriorated, and before the men could leave, a typical stretch of foul Welsh weather set in. There was no risking a trip to the mainland, especially after the waves stole the lighthouse boat. With four people eating rations meant for two, supplies soon ran low and spirits fell.

Desperate for help, the men wrote out a message to the local agent, sealed it in a bottle, and cast it into the sea. The waves carried the little parcel toward land, where it was picked up after the storm by a fisherman only a short distance from the home of the man to whom it was addressed. A boat was sent immediately to the Smalls Lighthouse. The rescued men were amazed that the plan had worked; the merciless waves had proven to be their salvation.

The *Daniel J. Morrell*

Skip Gillham



Great Lakes Graphics

The 600-foot long ***Daniel J. Morrell*** headed north to Taconite Harbor on Lake Superior for one more load of iron ore before the 1966 navigation season on the Great Lakes drew to a close. The 60-year-old member of the Bethlehem Transportation Co. fleet, riding without cargo, would soon encounter a violent late fall storm on Lake Huron that would take the lives of some of the crew and end its sailing days forever.

At about 0200 hours on Tuesday, November 29, 1966, the ship shook with a noise loud enough to awaken the sleeping crew. Winds of 50 miles per hour winds had whipped up 30-foot waves making progress difficult and uncomfortable. Suddenly, without warning the ***Daniel J. Morrell*** snapped in two just aft of the eighth hatch. The men in the powerless bow section could not even transmit a distress call.

The two sections of the freighter went separate ways with the bow sinking first. Four men safely evacuated on a raft, but by the time it was located 36 hours. later, only one sailor remained alive in the freezing temperatures. A total of 28 crew members perished that day.

The sunken stern section was easily located 16 miles due of Pointe Aux Barques, Michigan. The bow was not found until May 19, 1979. It is some 6.8 miles away and directly beneath the main vessel track up the lake.

During the same storm, yet another vessel would be affected by the Lake Huron waters. The upbound ***Edward Y. Townsend*** suffered a hull fracture and was immediately condemned. This ship eventually sank in the Atlantic enroute to scrapping in Spain.

Mediterranean Wave

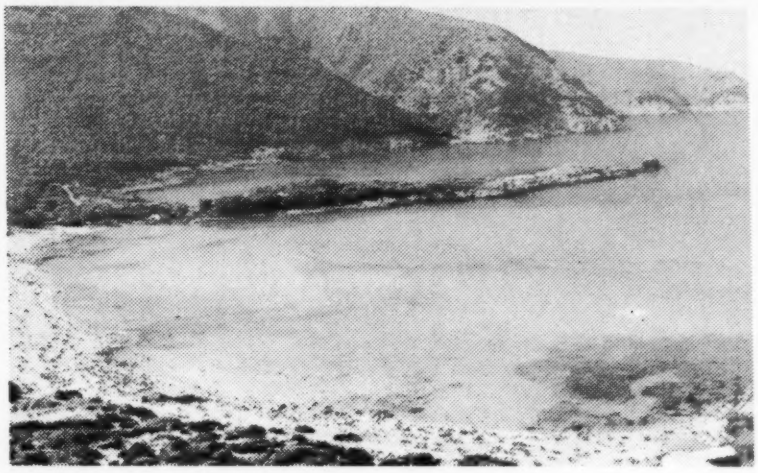
Geoff Potter, Captain USCG (Ret.)

Mariners always like to have a rational explanation for occurrences at sea. When friends gave an account of how a single wave wrecked their sailboat, I've wondered what exactly happened. I can still remember when, as a junior officer, I mentioned "freak waves" to an old salt (recently Vice Commandant of the U.S. Coast Guard). He corrected me by saying that there are "no *freak* waves, only *reinforced* waves." Notwithstanding that explanation, I am puzzled by my friend's recent encounter in the Mediterranean.

For the last 6 years, in between assignments, my wife and I have travelled the waters around Europe on our 35-foot sailboat. Last year while in the Balearic Islands, we were happy to meet up with some English friends Rhoda and Alan Cawthorne who had been cruising in their Vancouver 27 sailboat, ***Even Chance***. Now the boat was hauled out in Cala Ratjada—the mast had snapped, the bow and stern pulpits were badly bent or torn loose, and the handrails were ripped off.

The Cawthornes told us that in late August they had sailed across the Freu de Menorca (Menorca

*The **Even Chance** is a Vancouver 27 sailboat owned by Rhoda and Alan Cawthorne. During the wave encounter, its mast snapped while the bow and stern pulpits were badly bent and torn loose.*



At the top of the photograph is Cala Molta while toward the bottom is Cala Guya.

Channel) from Menorca into a strengthening Force 4–5 (11–21 knots) southerwesterly wind. They were glad to reach shelter in Cala Molta, a small bay open only to east and northeast. They spent about 48 hours there until the early hours of September 1. The wind shifted to the northeast and with 3–foot waves, sleep was impossible. They debated whether to leave but decided to wait for first light. About 0500 when Alan was in the cockpit and Rhoda was below, the boat was suddenly hit by one single wave which they estimated at 10–12 feet.

The wave drove ***Even Chance***'s stern backward down into the water; the spray cloths caused the stern pulpit to tear loose. They were then rolled sideways until their mast touched bottom and broke– Alan calculated, from the depth, a 135° roll. When they came upright, Alan was uninjured but thrown over the side and struggling to hold on. Rhoda was also uninjured but faced about 2 feet of water above the sole. The size of the wave can be substantiated by a 70–foot motor yacht in the adjacent Cala Guya which had its anchor chain snapped and was driven by the wind into the beach and rocks at the head of the cala.

When they recovered from the wave, the Cawthornes found their engine flooded out, and afraid that the boat would drag onto the shore, they rode their rubber dinghy into the head of the Cala Molta. The next day they learned that ***Even Chance***'s chain and anchor had held when a Spanish search and rescue boat towed their boat in for the lengthy task of cleanup and repair.

Now, the question is: where could such a single wave come from? I reconstructed from my log that a strong westerly had been blowing a few days before while we anchored on the rugged northwest coast of Majorca. The Cawthornes had had a southwesterly the day they arrived. Is it possible that these two swells, coming up each side of Majorca, met and reinforced at Cala Molta? But why one wave? And why after a northeasterly had been blowing long and strong enough to knock these swells down? Another slim possibility is that the wave was reinforced by a bow wave of a large inter island or Barcelona ferry. But I am not even sure these ferries use the Freu de Menorca.

The 20–mile wide Freu de Menorca averages a depth of 230 feet and rests on a northwest–southeast axis. Cala Molta is at the southwest side of the channel. Four miles from the northeast side of the channel lies the Puerta de Ciudadela on the island of Menorca. This inlet is 1/2 mile long, very narrow and quite shallow and lies on an east northeast axis. Some may remember that in 1984 a severe tidal wave travelled up the inlet and did a great deal of damage to visiting yachts and local boats. This incident was described, I believe, in a 1986 article in the American magazine *Cruising World.* A quote from the *East Spain Pilot,* a pilot book for yachts, describes Puerto de Ciudadela:

Under certain meteorological conditions, usually in the summer months and at night, a considerable scend can be experienced in this harbor, the water level rising and falling by as much as 1.5m (4.9 ft.) in a few minutes. Local fishermen can often give warning of this phenomenon, which is called rescarca and can be dangerous.

In writing, I hope to interest an oceanographer in exploring this phenomenon and then presenting a rational explanation for this damaging wave.

The Ramsey Lifeboatmen

Elinor De Wire
Mystic Seaport Museum

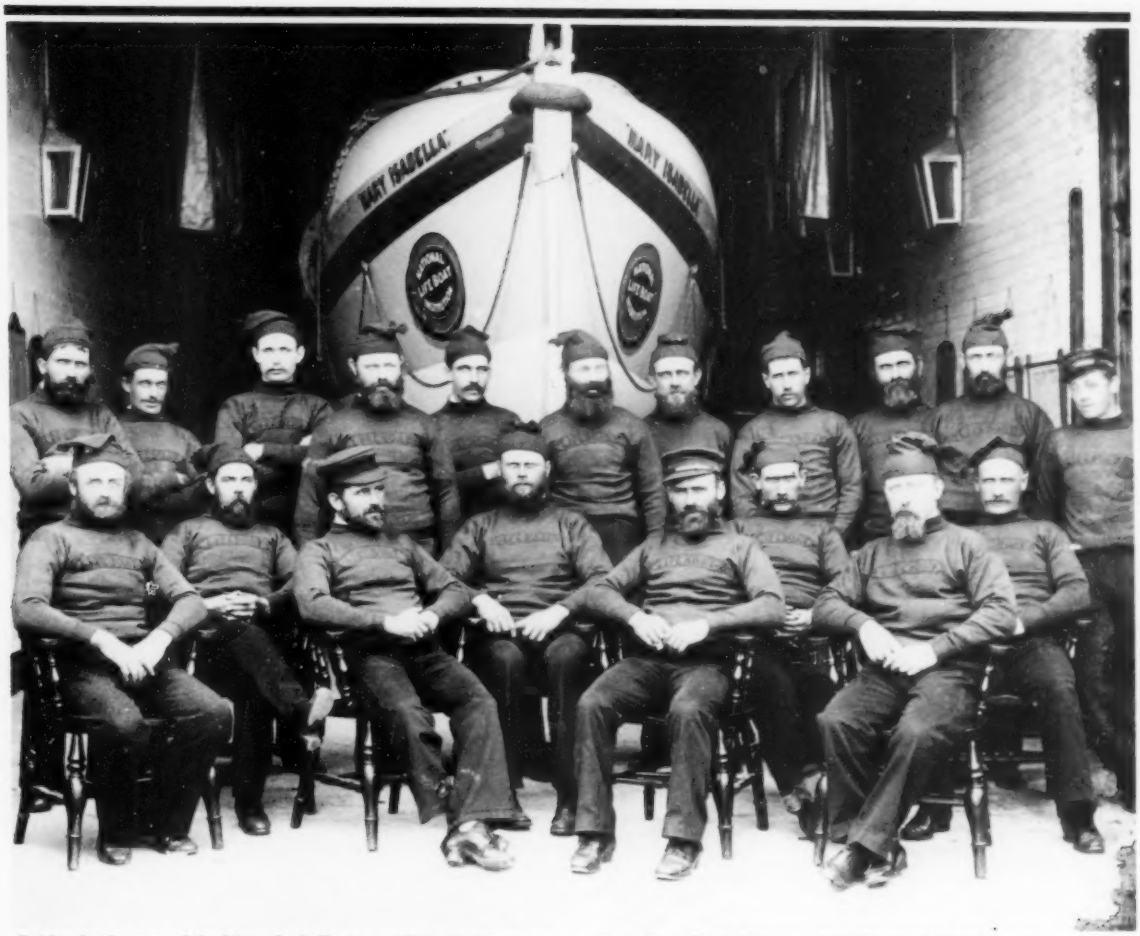
"There is a patch of land in the stormy Irish Sea called the Isle of Man, about which many traveled and untraveled Americans know scarcely more than its name," wrote a reporter for *Harper's New Monthly Magazine* in March 1875. The article went on to extole this much overlooked isle as a paradise nudged by the warm currents of the Gulf Stream and occupied by a gentle but sturdy folk who took pride in their independence and a long tradition of farming and fishing.

The writer neglected to mention that more than 500 shipwrecks have occurred along the Manx coast, most of these along the southern shores. Though a friendly little kingdom of a mere 230 square miles, the Isle of Man is separated from the rest of Britain by a sullen sea with a multitude of navigational hazards, particularly shallows, sandbars, and frequent fogs. It has often snagged ships traveling between Liverpool and Belfast.

But the Manx themselves appear to have suffered the majority of the losses. The Great Storm of September 1787 alone saw 60 fishing boats wrecked off Douglas Bay and 161 fishermen lost. There were no lighthouses on the Isle of Man at this time, and the life-saving effort that would later become known as the Royal National Lifeboat Institution was just beginning on the Lancashire Coast of England. Such disasters would be repeated until 1829 when the first lifeboat station was established on the island.

The Manx lifeboat stations owe their existence to William Hillary, a colorful character of some wealth who had waited upon England's sickly Prince Augustus Frederick and, in doing so, traveled widely. He eventually settled on the Isle of Man because of its pleasant climate and scenery and took up a leisure country life. The only drawback Hillary found was shipwrecks. The Manx seemed to have more than their share, many of which he witnessed from his home high atop Prospect Hill overlooking Ramsey Bay.

Hillary assisted at numerous wrecks, always aware that when men launched a rescue effort they were risking their lives. This fact alone made it difficult to enlist volunteers. The men did not fear death so much as leaving wives and children without a means of support. In 1822, when a naval vessel wrecked off Douglas Bay, and several Manx rescuers drowned trying to save the crew, Hillary used his contacts to secure small pensions for the families of the



Said to be the crew of the ***Mary Isabella*** *circa 1896. So far as can be determined those identified are: Back row L to R: –, Corkish, Walter Martin, "Ha" Gawne, Harry Corkish, Partridge, Tom Corkish, Charlie Godfrey, –, Joe Cottier, R. Kinnin, Willie Corkish. Front Row: Keppel Gawne, Bill (Danjou) Christian, Oscar Corlett (2nd Cox), Jimmy Cottier, Robert Garrett (Cox), –, W. McCormick (Bowman), Wm. Christian (nicknamed "Billie the Charmer"). Photograph from the Manx Museum and National Trust archives.*

lost rescuers.

The incident spurred ideas of an organization that would employ men to work as rescuers, that would be properly outfitted to do the job, and would provide pensions when lifesavers were killed in the line of duty. The effort came together in 1824 as the National Institution for the Preservation of Life from Shipwreck (NILPS). Thirty years later it was renamed the Royal National Lifeboat Institution (RNLI).

Thanks to Hillary, the Isle of Man was among the first places to be given a lifeboat. In the years immediately following the establishment of NILPS, official lifeboat stations were set up at Douglas, Castleton, and Peel. The most famous of the Manx stations, however, went into service at Ramsey Bay in 1829. All of these stations were crewed by the most able local men who drilled often and dauntlessly responded to calls for help.

Having four lifeboat stations on this small island was justified by the fact that between 1821 and 1846 nearly 150 ships wrecked in Manx waters. But subsequent years of fewer losses caused funding and interest in the stations to wane, especially after the death of William Hillary in 1847. The Ramsey boat deteriorated, and its crews languished until February 1861 when a powerful storm again exacted a toll in life and property and shocked the community. On the South Ramsey beach alone, eight

*Launching the **Mary Isabella** over the harbor wall during a blizzard in 1895 for a service to the schooner **Margaret and Elizabeth**.*

Below are four notable Ramsey Lifeboatmen with a total service of over 160 years during the period from 1875 ti 1931. Left to right are Harry Sharpe, Oscar Corlett, Keppel Gawne and Harry Corkish.

K. G. Groves' History

vessels were driven ashore.

The Ramsey Lifeboat Station was revived in 1864 by the establishment of a Rocket Brigade, with a crew of 25 men equipped with line-throwing gear. Four years later a new lifeboat arrived with its own crew– the 32-foot, self-righting ***Two Sisters***, named for the daughters of its designer. During its career from 1868 to 1891, 41 rescue calls were made and 147 lives saved. Its successor, the ***Mary Isabella***, had a shorter tenure but no less spectacular, due to the catastrophic storms of the 1890s.

Sunday, December 10, 1893 was one of the decade's worst days for the Ramsey lifesavers. The Isle of Man took the brunt of icy storm winds from the southeast. Within a period of about 4 hours the services of the Ramsey lifeboat crew and the Rocket Brigade were needed by four brigs and a schooner, and in the process the ***Mary Isabella*** came close to being lost.

As storm conditions moved over the island that morning, several vessels took refuge in Ramsey Bay, including two Norwegian brigs. The ***Sultana Reina*** out of Liverpool, with a cargo of cement, was in distress by midmorning. The Ramsey lifesavers launched the ***Mary Isabell***a for the 2 mile trip to the brig. They arrived in about 15 minutes and took off the crew of six. Nearby lay another brig, the ***Cormorant***, but since it showed no distress signal, the rescuers headed back to port.

No sooner had they offloaded the ***Sultana***'s crew than the ***Cormorant***'s anchor cable parted and

A. Christian Collection

fierce winds began to drive it seaward. The Ramsey men launched the lifeboat a second time, cheered by the crowd that had gathered on the pier to watch the ordeal. Seeing help on the way, the ***Cormorant***'s skipper intentionally grounded the brig, ending the possibility of a dangerous chase but necessitating that the lifeboat maneuver around the brig to take off the crew on the lee side.

Coxswain Robert Garrett ordered the lifeboat's anchor dropped to prevent the rescuers themselves from being pushed ashore, but the waves were so strong the anchor dragged. As the surfmen were driven helplessly toward the beach, an immense wave hit the ***Mary Isabella***, turned it on beam ends, and threw six men into the water, including the coxswain. Onlookers reacted quickly by pulling the men and the lifeboat from the surf. Coxswain Garrett came close to death; he was carried back out with the waves three times before being pulled from the water. It was a case of the rescuers being rescued!

With the ***Mary Isabella*** temporarily stranded, the Rocket Brigade stepped in and fired a line to the ***Cormorant***. The Norwegian crewmen, who were hauling a cargo of bran, did not know how to rig the breeches buoy, so one of the brigade was hauled out to set up the gear and oversee the rescues. When his feet were safely on dry land, the Rocket Brigade proceeded up the coast to the schooner ***Dairy Maid***. It had gone ashore too, but the lifesavers were not needed, as the tide was about to refloat it.

While the rescuers were busy with vessels at Ramsey Bay, farther north near the Point of Ayre Lighthouse the brig ***Gier*** had wrecked and was breaking up in the waves. As soon as the ***Dairy Maid*** was found safe, the lifesavers rushed up the coast to assist the ***Gier***. Islanders had already begun the rescue by getting a line to the ship and forming a human chain along it. The battered crewmen were taken off one at a time and handed along the chain. Lifesaving Medals were awarded to a number of brave people, shore residents included.

Royal National Lifeboat Institution

The Ramsey Lifeboats 1829 – 1991

232 pages of details on the boats, the men and the services with 150 illustrations.

Available from the author:
Captain W. N. Seybold, "Cair Vie"
36 Ballaterson Fields, Ballaugh,
Isle of Man.
Price £12.95 plus £3.00 postage per book (UK), £4.00 Overseas.

All proceeds to the RNLI

Manx Museum and National Trust archives

How High Can Giant Waves Get?

Dr. Joseph Goldman
International Center for the Solution of Environmental Problems

What's the highest possible wave that could occur? Each year more data becomes available from ships, satellites, and weather buoys which changes the base for calculations on maximum storm waves. This information is essential in designing platforms and drilling rigs.

As a research meteorologist and technical director of the International Center for the Solution of Environmental Problems, I've found that every time we get more operational forecasting experience, we find out the probabilities have to be updated—not downward—but upward. I have asked many, many times 'What's the limit for wave design?' This was something of a challenge and the center went to work on it. In time, we developed four computer models for the expected storm conditions that provide interesting insights on storm wave heights.

A search of available environmental design data showed the estimates for storm conditions usually contained one maximum wave per storm. It should be stressed that it is *not* one wave per storm. Each storm has a distribution of waves related to the distribution of both wind and swell. To properly assess the exposure of a site to the storm, both the spatial distribution of wind, wave, and swell in the design storm as well as its frequency of occurrence should be considered. This means that design criteria may have to contend with the long period associated with the combined sea and swell.

Four conditions are necessary to produce the maximum wave:

1. The age of the storm must be at least 12 to 24 hours. It takes at least 12 hours to get a steady flow of wind to build an equilibrium sea state. The same minimum length of time is needed for the Coriolis force to balance the wind.
2. The weather system must be dynamically stable. It has to last in the storm state for at least 12 hours.
3. The geographic area where the storm occurs must be able to support a very deep low pressure zone. Two areas in the Northern Hemisphere qualify—the Gulf of Alaska and the North Atlantic near Iceland.
4. The storm must stretch over a long area with an undisturbed fetch.

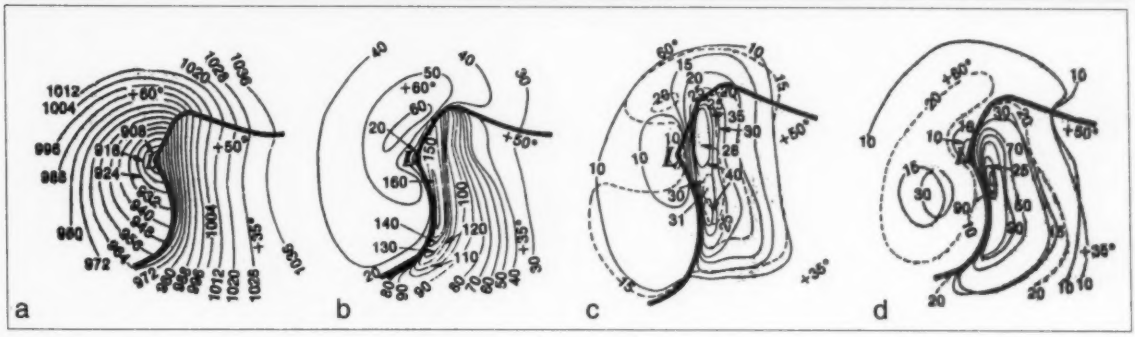
In order to model the storms, it was necessary to find the places where there were very large areas of open water and where the weather system could proceed without hindrance.

Two models for each of the four storm systems were prepared to represent developing and mature states of storms. Models were based on four factors: the pressure gradients in front of the leading edge of the cold front must be steep; winds must blow at a steady rate along the area over a distance of several hundred kilometers; swells must be built up, and waves of long periods must build up also.

In the storm system illustrated at the top of page 49, the fronts run from about 35° North to about

Dr. Joseph Goldman is a research meteorologist and technical director of International Center for the Solution of Environmental Problems based in Houston, Texas.

This article first appeared in Ocean Industry *magazine, June 1978, Vol. 13, No. 6. Dr. Goldman says he continues to stand by the theories presented in this article 15 years after its first publication.*



Storm systems with these characteristics must develop in areas such as the Gulf of Alaska or the Atlantic Ocean near Iceland. Pressure gradients range from 900 to 980 millibars (a) over a distance of 150 kilometers. Wind speed must remain steady for a long period with speeds from 90 to 160 knots (b). The wind will build up swells (c). A long period for the storm is needed to build up significant wave heights (d).

55° North. Pressure gradients range from 900 to 980 millibars (a) over a relatively short distance, 150 kilometers. Maximum winds speeds are from 90 to 160 knots (b).

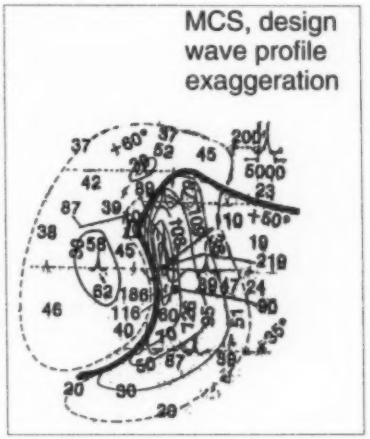
The long fetch and the high wind speed build up the waves to as much as 110 feet. The solid lines indicate the significant height of the waves and the dashed lines, the significant period in seconds (c). At the same time, swells are built to heights up to 40 feet (d), where the solid lines are the swell heights and the periods in seconds are represented by the dashed lines.

With these conditions, a maximum combined sea height of 219 feet is possible. When it occurs, it's going to be in water at least 281 feet deep and will have long periods.

In the exaggerated design wave profile at right, the unattached numbers represent data points and the maximum wave heights measured there. Those numbers attached to lines show the areas of significant wave heights.

These types of waves are possible only with an elongated system. Even massive typhoons in the Pacific Ocean cannot generate these types of waves because the circular motion of the storm resists the fetch and does not allow the large swell to combine with the large waves. It is possible to get a 70- to 100-foot wave in a circular type storm but nothing approaching the maximum magnitude of the wave. A 73-foot wave was measured in a Gulf of Mexico hurricane. The pressure and wind distribution of that storm indicated that higher waves escaped measurement.

In developing the models, we started with a pressure field that can last in the atmosphere for at least 24 hours. From the pressure field, we calculated a gradient wind field. We took the wind field and put it over the ocean and generated a sea state, and from that calculated the swells as well. We mixed the two at specific points in the system into what we call a combined sea state and determined the waves and swells and their periods around the whole system. I might add, the wave generation method generally based on the work of Dr. Charles Bretschneider, a specialist on waves and ocean engineering, contains a themodynamic factor that restricts the sea build-up to the air/sea temperature difference. Other hindcasting methods that don't use the thermodynamic factor would generate significantly higher waves from the same wind distribution. Comparison of operational forecast data with measurements at offshore sites during storms verify the importance of the thermodynamic factor.



The resulting storm produces these maximum wave profiles.

The models can be applied to any remote offshore area where comparable storms take place. Fetch restricted by the land mass distribution near the particular site, and

the water temperature distribution would determine the resulting configuration of the sea and swell heights and periods for that storm. The "risk" or insurance exposure is calculated from the frequency of occurrence of the storm and the probability of encountering the various maximum conditions within the storm.

Environmental studies done in the late 1970s, such as ones performed for Seadock Inc., a company involved in ocean engineering, indicate the importance of determing the proper location of offshore operations not only in space but in time, within the climatic cycle. Over design and perhaps underdesign may result from improper application of an offshore measurement program that is necessarily restricted to several months due to costs. Determining the operations period within the particular mode of the climatic cycle can minimize the chance of misinterpreting the valuable results of the offshore measurement program.

Other studies have shown elusive trends in climatic data that are significant downwind of urban areas. Intensive study of the available data reveals these trends. This type of study is "off-the-shelf technology" and can be used for offshore design.

Besides the Gulf of Alaska and the Iceland area, the Weddell Sea off Antarctica is another storm generation area that produces waves up to 100 feet but for different reasons.

The Gulf of Alaska and the Iceland area are unique because those are the areas where continents come together. The combination of the land mass curvature with the availability of warm surface water at those locations contribute to increasing air circulation and convection which gives rise to the intensified or reborn low pressure areas. In the Southern Hemisphere, I am sure there are comparable storm generating points, but they are not as distinct as in the Northern Hemisphere and we haven't found them yet.

U. S. Navy

If anyone ever sees the Big One, will they live to tell the story? How many mariners may have already seen such waves on the many missing vessels over the centuries?

The weather information in the Northern Hemisphere is greater because of the concentration of land and people and the increased shipping that goes on there. Except for the trade routes in the Southern Hemisphere, very little is known about storm conditons or even average conditions at offshore points. Comparably little is known about storm conditions generally anywhere on Earth because no one is going to be taking measurements willingly in a storm. One of the biggest problems we have in determining maximum storm conditions is a lack of data. Ships try to avoid storms in general and always avoid the worst parts of storms when possible.

Sea & Storm Service Specialists in Great Britain use satellite data to detect, survey and help predict weather systems and sea states for the North Sea and North Atlantic. Satellites have proven exceptional tools to detect and keep up with the storms. Researchers are still learning to interpret the satellite data in terms of wind, wave, and swells.

While developing the models for the storms, I assigned an associate the task of recording pressure data from daily weather charts. The associate came running in one day with a chart which showed a duplicate of the pressure gradient we were trying to model and noted that the waves from that storm would be near 70 feet. Sure enough, later reports confirmed the prediction--which was based on pressure gradient.

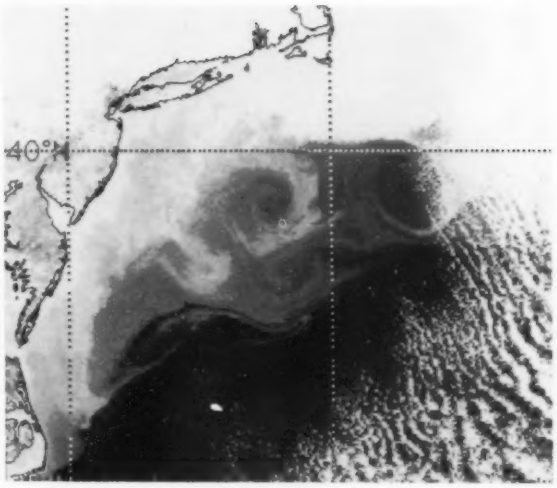
A Gulf Stream Phenomenon

Jenifer Clark, Larry Breaker and Vladimir Krasnopolsky

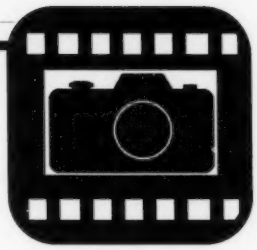
In late October 1990, an unusual phenomenon occurred across the Gulf Stream about 200 miles northeast of Cape Hatteras, NC. In the polar orbiting AVHRR infrared satellite imagery acquired on October 30, 1990, the Gulf Stream appeared to have separated into two segments. There was a horizontal filament of cool water (light gray) being advected across the Gulf Stream (dark gray) near the center of the image creating the illusion of a "broken" Gulf Stream. This thin cool filament was about 5 miles across and 4–6° C cooler than the Gulf Stream north and south of it. This wedge-shaped cool filament was apparently Continental Shelf Water interacting with the northern edge of the Gulf Stream. Features of this type have been only rarely observed before.

In order to reconstruct what may have occurred in the vicinity of this Gulf stream interaction, it was important to review the meteorological and oceanographic events that took place before the appearance of this phenomenon. Cold shelf water was observed being advected along the north wall of the Gulf Stream on the 28th of October, just east of Cape Hatteras. At about the same time, anomalous meteorological conditions occurred off the Cape Hatteras coast, producing strong persistent northerly winds of about 30 to 40 knots. Satellite imagery on the 29th of October revealed what appeared to be cold shelf water embedded in the Gulf Stream. By the 30th, this feature had been advected along the Gulf Stream northeastward. Its downstream velocity was calculated at 3.5 knots, which is consistent with average Gulf Stream flow.

This cold shelf-water filament was tracked for several more days until cloud cover prevented viewing. Cloud cover decreased enough by November 16th to show the northern edge of the Gulf Stream again, and a cold wedge-shaped filament about 300 miles east of Cape Hatteras (near the right edge of the image) was embedded in the Gulf Stream. Calculating the downstream velocity of this feature showed velocities consistent with the flow of the Gulf Stream over this region.



Unfortunately, there were no subsurface expendable bathythermograph (XBT) data available for this time period in the area. XBT data could have been useful in determining the depth of the cold filament (just a thin surface phenomenon or perhaps it penetrated to some depth). Since it did persist for several days, one might infer that the cold filament was more than just a thin surface phenomenon.



The Man from Waves

Michael Halminski

Growing up in a Navy family, I usually had the good fortune of living near the sea. Maybe this is the reason for my fascination with waves. It's not too surprisingly then that as a teenager I learned how to surf, and some years later made my home on Hatteras Island in a town called Waves.

Living here has been a boon. Over the years I have honed my craft as a photographer on scenics and nature in an area renown for its beauty. Storms at sea especially create potential subject matter for my camera.

Working with still photography dictates that I "freeze" a particular instant in time, so it's important to study the circumstances and strive for decisive moments to take the picture. This is particularly important when the subject is moving or changing rapidly as does a stormy sea. Try to shoot the peak of the action. Some waves are larger and more powerful than others. Wait for the big ones and shoot them as they crest and break in front of themselves. Study your perspective and orientation to the sunlight, and move around if possible to make your picture more effective.

I particularly enjoy the advantage of switching to different focal length lenses. Wide angle lenses are good for concentrating on foreground details, leaving far away details almost unobservable. The stronger telephotos tend to isolate things, for example, the top of a peaking wave. I like to use medium telephotos in the 100–200 mm range, especially my 135 mm, to get some of the advantages of both wide angle and telephoto worlds.

Most of the time when I shoot from shore, I can easily move about and change my angle in relation to light and subject. At other times, a more difficult strategy is shooting from the water where perspective can be intimate and dramatic. I've done this while swimming if conditions permit and on a few occasions from a boat. The latter method is one that has long captivated me. Few powers on earth can compare with the dynamics that high winds have on the open ocean waters, and I've always admired photographs taken from ships in storms at sea. I also have to admire the people taking the photographs. Although I would love to have such images in my portfolio, I don't envy having to be in such uncomfortable situations, nor have I had the opportunity as yet.

Photographs of this nature have more impact or interest if they are given some scale or comparison by including a vessel or even a portion of a vessel in high seas. With such close proximity to the subject, in addition to uncontrolled camera movement, I would only recommend wide angle to normal lens ranges.

However you go about photographing the oceans in its different moods, whether it be from land, sea, or even in the air, remember to take precautions to protect yourself and your valuable equipment from the adverse elements of the marine environment.

Hurricane surf (page 53, top) from a storm centered 200 miles off the Hatteras coast. Notice how using a 135 mm focal length lens allows some foreground and brings in the power of the surf.

In the bottom photo on page 53, a good south swell is rolling into a northwesterly wind. Offshore winds are preferred by surfers because they hold the wave up longer. It also enhances a beautiful photographic subject.

On the back cover, is the surf during the Halloween Storm of 1991. Note again how the 135 mm lens compresses the foreground and the pelicans help give the waves scale.

President Madison and the Christmas Day Typhoon

Archie K. McLaren

One of the problems with old people like me, living well beyond the three score and ten years, is that we tend to reminisce. On one of my infrequent visits to the Seattle area, I found my sister plying me with questions about what I recalled of the days I sailed on the ***President Madison***. I thought she was referring to the freak accident that occurred to that vessel while moored at a dock at Todd Shipyard back in the early thirties. Actually, I knew very little about that accident since I had been transferred to another American Mail Line ship.

No, it wasn't the Todd Shipyard incident that she wanted to know about. There was another event in the history of that ill-fated ship that came very close to ending with a disaster at sea.

Now that I think about it, I wonder how many people are still alive today out of the three or four hundred passengers and crew who remember being on a 14,300-ton vessel that nearly capsized in a raging hurricane on or about Christmas Day, 1930. It actually happened, you know, and there must be a few around who can recall the events from a different perspective than mine as an Assistant Purser.

Capt. David C. Austin was the Master of the SS ***President Madison*** when it left Seattle that trip. I believe we left at the usual time on Dec. 13, 1930, bound for Yokohama, Japan, with a 2-hour stop at Victoria B.C.

The Great Circle Route from Puget Sound to Yokohama is usually a moderately rough trip even in the summer months. On this December trip, as we passed Cape Flattery, the weather was not only rough, but a better word would be miserable. The further west we travelled the heavier the seas, with winds from the northwest.

This voyage of the ***President Madison*** was hardly a moneymaker. There were about 20 first class passengers, and about 200 in steerage class. The latter were usually Cantonese, many of whom could afford to travel first class, but preferred steerage where there were gambling games going on nightly.

Transpacific crossings on the ***Madison*** were often a lot of fun. The ship's orchestra would play for dinner dancing most every night. Captain Austin would lead off

Archie McLaren is now retired but still travels. In his own words: "Now at the age of 85 , I am quite content to limit my sea voyage to once every 12 or 15 months but only as a paying passenger. My recent trip to Alaska on a 190-foot passenger vessel called ***The Spirit of 98*** *was made to revisit the inland passage to Southeastern Alaska and visit areas where shipping never travels. It was a treat for me to pass the point on Work Island where I was shipwrecked back in 1946."*

This article first appeared in the June 1989 issue of **Sea Chest**, *a publication of the Puget Sound Historical Society.*

Thanks to George Broom & Sons, Sailmaker who loaned us the great photograph mentioned in the text.

dancing with a lady from his table, with the orchestra playing his favorite tune, "Moonlight and Roses." It was played so often for him on so many voyages, that he finally grew tired of it. On this trip there was no dinner dancing any night. In fact, for the most part it was almost impossible for the orchestra to carry out their duties. As we continued to travel westward, shipboard activities became more restricted.

However, our real problems began when it became necessary to bring the ship around away from the head winds and into the trough of the sea with the stern to the wind. This was done to permit the deck crew to make emergency repairs on No. 1 hold where the seas had dislodged a hatch cover. As it turned out, the damage to the hatch covers could not have occurred at a more inopportune time. The gale increased to hurricane force. I believe the ship's log recorded the wind as having reached Force 12, which was in the neighborhood of over 100 miles per hour. The seas were mountainous– over 70 feet high according to many in the crew. When Captain Austin tried to head the ship into the storm again after repairs were made to the hatch covers on No. 1 hold, we all came very close to an untimely end.

Just how it happened only those on watch knew, and it is doubtful if they were too sure. But every soul on board became aware that the ship keeled over to the starboard side at such an angle that it would have been just as easy to walk on the walls of cabins and passageways as it would be to use the decks. Most people spent their time in bunks or beds rather than trying to move around the vessel. Normally the ship righted itself from such a heavy roll. Not this time. We simply rolled over on our side and hung there for a couple of minutes. Who knows how long it was. We all agreed it seemed like an unnaturally long period. When the ship rolled back to something resembling an even keel, Capt. Austin brought the ship back into the trough of the sea. For at least 2 days there was no normal activity anywhere. We closed the Purser's Office. Passengers and crew alike consumed cold sandwiches and hot coffee, if they wanted to go and get it in the galley. Transporting hot coffee from one part of the ship to another was very risky business. Service in the first class dining room was impossible. Some of the tables were uprooted from the deck where they had been secured with bolts. As a matter of fact, the deck crew was able to secure the grand piano in the main lounge just before it was starting to travel on its rollers. There was considerable damage to furniture.

Paul Lutey was the freight clerk that trip. Just before we left Seattle he had managed to pick up

a used Graflex camera like the ones news photographers used in those days. Paul persuaded Oliver Goudy, the baggage clerk, to accompany him up to the boat deck so Paul would have someone to hang on to him when he took a picture of an extra high wave. The picture was an unusual one and attracted a great deal of attention among the passengers– everyone wanted a print of that picture. The ship's printer had a small developing business with the crew members for customers. This time he cleaned up selling copies of the picture. Most of the 120 Chinese crew members in the steward's department made very little in wages. So, if they were not working where the tips were good, or operating one of several gambling games in the steerage, they didn't have much to take home at the end of the voyage.

The printer had a nice business going with the sale of these pictures with the inscription on the negative until the general passenger agent learned of the success of his enterprise and put a stop to it. That kind of publicity he could do without.

After a good 24 hours of wallowing in the heavy seas, life aboard became very trying. It was our understanding that the skipper did not want to take another chance in heading the ship back into the storm. He apparently thought it prudent to wait until the wind abated to get back on course. Some time late in the second day of rolling, the Chief Engineer went up on the bridge and had a talk with Captain Austin. Details of that conversation did not come out until days later. But as described by the deck officer on watch on the bridge at the time, our Chief Engineer turned out to be a very remarkable man. In addition to holding an unlimited Chief Engineer's license, he was also licensed as Master of sailing vessels.
The story goes that the Chief encouraged the Captain to try heading into the seas again. This time the two men used their combined experience to cope with the project. The actual details of which engine was placed on "Half Ahead" and which on "Half Astern" and which way they had the rudder turned, doesn't matter now. If there are any surviving witnesses, they might take a guess. I am just able to relate that the two of them brought the ship around back on course without further disastrous rolls. I have never heard it said that this Chief ever related a single word about the part he played in getting the ***President Madison*** back on course on or about Christmas Day, 1930. I recall that he was a very quiet man and very well liked by everyone aboard.

I was just 22 years old at the time. I hadn't had enough time at sea to know that I should have been scared stiff. I simply looked at the whole episode as an adventure– one that would provide fodder for a sea story when the trip was over and stories could be told.

Later on, when we finally reached Yokohama shortly after New Year 1931, I came across some former shipmates while having a beer in a bar.

It wasn't long before I was relating the gory details of the storm and how far we rolled over and hung on before righting. I must have made it sound that anyone going to sea hadn't seen anything until being aboard a ship that rolled 45 degrees in a heavy sea. In any case, I was interrupted by Roebuck, the fourth mate sitting at the next table.

Roebuck scolded me for being stupid. Didn't I have enough sense to realize how close we all were to being buried at sea without a trace? Furthermore, he pointed out, we could all thank the fact that the ship had been carrying a big cargo of copper ingots from the Tacoma Smelter. The fact that the cargo was properly stowed in the lower holds and between decks was the only reason the ship recovered from that roll and we were all alive to talk about it.

Had the same event occurred on the homebound voyage, the ship would have gone down with the loss of all hands. We always returned from Japan with a fairly light cargo, so the ship was higher in the water than when we were outbound from Seattle. Roebuck pointed out that no 535 hull was designed to recover from a roll of 45 degrees or more.

Since that Christmas in 1930, I have made many voyages across the Pacific and many to Alaska as well. There were times during the years that I experienced some very rough weather on one voyage or another. However, as far as I am concerned to this day, I only experienced one real storm in the many years I spent at sea on the Pacific Ocean.

But to a prospective traveller who might be reading this story, there is a bright side to consider. Modern science has changed many things during the past fifty-odd years. No ship's captain would ever find himself facing a hurricane like the one the ***Madison*** did back in 1930. All ships would make a wide detour to avoid such weather, having been forewarned.

NOTE: For additional information on the ***President Madison***, please see the December 1983 issue of *The Sea Chest*.

The End of the Radio Days

Rick Booth
U. S. Coast Guard

CQ DE NMF/NIK 0100012 1993 BT
QUOTE NOW CLOSING DOWN CONTINUOUS
WATCH ON 500 KHZ AND CEASING ALL
MORSE CODE SERVICES IN THE MF
BAND. WE WISH THE MARITIME
COMMUNITY FAIR WINDS AND
FOLLOWING SEAS. WE ARE PROUD
OF OUR TRADITION AND LONG
STANDING SERVICES ON MF

An era ended July 31, when the Coast Guard suspended its radio operations on 500 KHz morse code, a service in continuous use for almost 100 years. At Communications Station (CommSta) Boston in Marshfield, MA, RM2 Chris Bush tapped out the final message for mariners on station NMF's thousand-watt medium-frequency transmitter, as the station clock ticked toward midnight "zulu time," or 8 p.m. Eastern Daylight Time. It was the end of the radio day on the last day of U.S. Coast Guard "cw," short for "continuous wave" or morse code in the medium frequency (MF) band. Advancing technology and international treaty have rendered morse code largely ineffective as a lifesaving communications medium, and Coast Guard headquarters determined to suspend the 500 KHz service weeks ago.

The Coast Guard received its first morse cw distress call in 1905, a little more than 4 years after the first Coast Guard experiments in the then-revolutionary communications medium of radio. An operator on a relief lightship at Nantucket Shoals copied the word "help" followed by an appeal for rescue.

In the decades since, Coast Guard radiomen have answered literally thousands of cw distress calls, and copied untold millions of messages, as well as sending messages and information of vital importance to the maritime world.

For years, the ability to send and receive morse, often under difficult conditions, was considered the hallmark of a good radioman. Salty old *sparks* sniffed at newer arrivals in the radio shack, waiting for them to prove themselves on the air. CommSta Boston offered one old *sparks* the privilege of representing his contemporaries, and those who went before, as a participant in the July 31 final transmission.

Before Bush took over the simple hand key—the same kind used by his progenitors in the dawn of radio—retired LCDR Ralph A. "Rusty" Hemenway had been offered the privilege of sending the message preamble. Hemenway retired in 1992 as chief of the First District Data Telecommunications (dtm) Branch. Prior to obtaining his commission, he had been a radioman for many years and known as an excellent cw operator. Hemenway sent this message:
CQ CQ CQ DE NMF/NIK NMF/NIK NMF/NIK
010001Z 1993 NOW CLOSING DOWN CONTINUOUS WATCH ON 500 KHZ, AND CEASING ALL MORSE CODE SERVICES ON THE MF BAND. GOOD LUCK TO YOU FM (from) OUR SAD SPARKS. FAIR WINDS AND FOLLOWING SEAS WITH 73s (best wishes) FROM ALL OF US AT NMF/NIK TU SU AR VA.

The final characters "tu su ar va" are morse conventions for "thank you," "see you" and two shorthand "prosigns" for "end of transmission."

Bush then followed with the actual message text, written by several NMF operators in a collaborative effort. The addition of "NIK" in the message preamble refers to CommSta Boston's callsign for the International Ice Patrol. Hardly had Bush finished sending the traffic than stations called NMF, anxious to contact or "work" the Coast Guard's last MF cw operator, and so become part of history themselves: the Canadian schooner ***Bluenose***, calling from the Caribbean; Canadian station VAU from Yarmouth, Nova Scotia, and commercial cw stations WSC in West Creek, NJ and WCC, located at Chatham on Cape Cod and themselves a rich part of morse code's epic tapestry. Bush answered all in the steady, clear hand of

The King of Comms enjoyed a long reign

If anything signals technology's march, "comms" do. Traffic that once took hours to send by hand, moves in seconds through computers. Today's radioman is much more technician than the artists of yesteryear–so much so that the Coast Guard is considering a change for the rate's name. But computers and morse code, or "cw," have more in common than many realize. In its purest form, a computer can only understand two states: on and off. All digital technology can be reduced to those two. So it is with morse code, which was invented even before radio, as a means to send information by wire. An operator turned a transmitter on an off, in a specific sequence, to create short and long bursts of sound–the familiar "dot" and "dash."

Those combinations of dots and dashes were, for years and years, the *only* way to send traffic. And even after the advent of newer modes–AM voice, single sideband and more lately digital– cw retained the title as best in the bunch. So radiomen, real sparks who could send and receive the code flawlessly and at great speed, were the heart of Coast Guard communications, and indeed all maritime comms. Why was code king for so long?

For one thing, cw is simple, just a transmitter turning on and off. Consequently, it is inexpensive. Its signal is very narrow, allowing more communication in a smaller amount of radio "spectrum." And it is reliable. When atmospheric or other conditions scramble voice modes, the traffic always got through on cw, sometimes with very little power.

But it is slow. In *real* cw, the kind sent by hand, each character must be formed by the sender's *fist*, heard by the receiver's ears. Since operators are human, their sending varies. Slightly, in the best of them, but it varies. Each has his (and, more recently, her) own fist. Good operators can recognize others: "There's NML; it must be Joe on the key, I recognize his fist." Code must be learned by the sense through which it will be used: ear for radiomen, eye by quartermasters, who will send/receive flashing lights. Like a foreign language, skill progresses to where not only does an operator not hear individual dots and dashes– the brain literally takes itself out of the loop, and the characters, words and sentences form full-fledged on the conscious. Intelligibility is dependent on how well the sender makes the dots and dashes–and the all-important spaces in between. A good *fist* is easy *copy*, and its owner commands respect.

Because of its economy and simplicity, cw is still used by a considerable number of the world's merchant vessels, and even the military, especially in developing nations. Amateur radio operators like the mode too, conversing in it, carrying traffic for practice, and even engaging in on-air contests to see who can *work* or contact the most stations in a given amount of time.

These factors forge a kinship among code operators, a bond hard for the uninitiated to appreciate. Professional or amateur cw devotees will forever seek one another out, remembering the times when "sparky" carried the mail, and forever recalling the colleagues whose emissions meant so much–more than once, the difference between life and death.

a fellow professional, sending "seventy-three" to each, radio shorthand for "best wishes" and–like many code traditions–one whose origins are lost in the mist of radio antiquity.

The CommSta personnel had invited a delegation of amateur radio operators, or *hams*, representing the American Radio Relay League, ham radio's umbrella organization based in Newington, CN to be on hand. They watched as Hemenway and Bush sent the final message. Amateurs have a rich tradition in cw, and will continue to use the mode, both for fun and should an emergency arise, to "carry the traffic" when called on. The invitation was extended as an acknowledgement of amateur contributions to cw and other modes.

As the last dot-dash notes drifted through the CommSta operating spaces, CWO Mike Darling turned to his commanding officer, LCDR Bob Day, and the radioman-in-charge, RMCM Jay Powell. Darling expressed the mixed feelings of many Coast Guard and other communicators. Constantly striving for new and better modes to aid communication in general, and search-and-rescue in particular, these people knew better than most the value of the modes replacing morse. That the old must make way for the new, there was no question. But Darling and Powell, each of the old school, were fully aware of the moment's meaning–of what was going away.

"You know sir", Darling said to Day, nodding at the cw booth, "in a way, I'm sorry to see it go."

This recently appeared in the U. S. Coast Guard's First District publication First Word. *Thanks to Rick Booth for a fine article.*

PMO Report

Bob Novak
PMO Oakland, CA

The National Weather Service is modernizing and one of the new tools will be Doppler Radar. Along the West Coast of the United States, some of these radars will be located atop coastal mountain ranges. The seaward extent of these radars will be about 125 nautical miles. Some will have the potential to see storms as far as 250 nautical miles at high altitudes.

These radars will be the first of their kind along the West Coast. One has already been installed at Vandenburg Air Force Base (Point Arguello, CA). Over the next 2 years, radars will be installed near San Diego, Los Angeles, San Jose, and Eureka, all in California. Additionally, radars will be installed near Portland, OR and Seattle, WA.

During the first few years after the radars are installed, ground/sea truth information will be important to help us to scientifically evaluate what we are seeing. Ground/sea truth information will be provided on land by automatic gauges and other surface observations. Over water our data will be provided by buoys and ships. Currently, the density of buoy and ship reports are not enough to provide us with a good scientific data base for study.

Additional ship reports, especially during periods of stormy weather, will help augment our data sources. If ships traversing the Pacific Coast could take two or more synoptic observations and transmit them, this would help augment the data base.

What will the mariner get out of this? Each new radar has the ability to detect significant marine elements such as wind, waves, fog, and the sea/land breezes. The information obtained from the radar will improve storm warnings as well as forecasts.

We need mariners help to verify what is indicated by radar. If you use our weather, please share your weather with us. Only you know what the weather is really like at your position.

The standard reporting times are 0000, 0600, 1200, and 1800 UTC. A 3-hourly reporting schedule is in effect if vessels are within 200 miles of the U.S. coast and within 300 miles of named tropical storms.

I know the problems faced by the deck officer while traversing the West Coast. Lots of targets on radar, fixes and bearings every 6 to 12 minutes, etc. The worse the weather, the busier you are; the faster you hurry, the behinder you get. If you can time manage it, please remember to report the weather. See you soon.

Above, Captain Gunnar Tangen, Master of the ***Sea-Land Atlantic*** *receives a 1992 outstanding award from Jim Nelson, PMO, Houston. Second mate William F. Toomey is off camera.*

The Ray Brown Show

Above, left Norfolk PMO, Earle Ray Brown, Jr., stands by Executive Officer, Pete Celone, after presenting him with the award for outstanding observations in 1992 for NOAA's ***Albatross IV.*** *In the photo below, the Virginia International Terminals, Vessel Operation Office receives an award for their continuing support for the PMO program. From left to right, Bland V. Creekmore, Thomas H. Martin, Ray Brown, and Ernie H. Dunn. Happy Retirement to Tom.*

Ray Brown thanks Stephen F. Galloway, Manager of Operations for Lykes Lines Steamship Company at the Lykes Bros. Norfolk office (above). In bottom photo Brown discusses VOS and SEAS Program with people based at Fort Eustis, VA. From left to right, Chijioke Ibe from Nigeria, Ray Aube, U.S. Army, Jim Farrington, SEAS and Ray Brown.

***Sea Merchant** Chief Mate, Bernd Banck, holds the VOS award for the third consecutive outstanding year of observations (above left). Below left, Ray Brown congratulates Capt. Karl W. Popp who accepts his award on behalf of the USNS **Mohawk** and its previous captain, David W. Muir.*

*The PMO stands with some of the crew (upper right) of the **Abou El Burakat Al Barbari** formerly the USNS **Bartlett**. The ship was sold to the Moroccan Government's Hydrographics Office. Brown recently gave VOS training and necessary supplies to the crew. In the photo upper right, are QM1 Mohamed Touali, 2nd Officer Mustapha Laghman, PMO Brown, and Capt. Abderrahim Najib.*

Gifts go back and forth at the M.S.C. TAGOS Unit, Atlantic Little Creek Amphib Base, VA. Brown presents a support award to the unit and receives a T-Shirt in return. Left to right in photo below are David N. Hallden, CDR Patricia A. McFadden, Brown, and Robert R. Swanbeck.

*Oakland PMO Bob Novak (not in photo, unlike Nelson) presents the 3rd award for weather observations to Captain Arthur K. Jaskierny of the **Sealand Pacific** (above left). **Sealand Navigator** receives its first VOS award in Oakland from Bob Novak for PMO Bob Webster, Los Angeles (below, left). Left to right are Captain Forsberg and Chief Mate Michael Perry.*

Chevron Corporation workers accept Bob Novaks' thanks (top,right). Left to right are Lou Lanza, Senior marine Superintendent; Marsh Clegge, Pacific Region Fleet Manager; Dave Powell, Fleet Manager; Captain Tony Morey, Fleet Master; Bob Novak, PMO; and Dave Caldow, Atlantic Region Fleet Manager.

*Another Bob Novak VOS observation plaque (below, right) is awarded for the third time (left to right) to Chief Mate Rich Van Der Lann, Chief Mate Bill McKinley, and Captain Ray Wood of the **President Washington**.*

*The **Arctic Tokyo**, a long reporting Voluntary Observing Ship (VOS) vessel was decommissioned on July 31. The Liquid Natural Gas (LNG) carrier was retired from the Polar Fleet and sold to a British Company which will completely refurbish the vessel and return it to duty in the Mediterranean. Commissioned in 1969, the **Arctic Tokyo**, with a gross tonnage of 48,454 was under to command of Captain Gaetano D'Agostino. The ships' route was from Nikisi, Alaska to Yokohama, Japan. Recruited in 1980 from Los Angeles (LAX), the **Arctic Tokyo** has been an outstanding reporting vessel. The replacement vessel, the **Polar Eagle**, is both new and larger with a gross tonnage of 66,174. Captain D'Agostino will command the vessel which will continue the Nikiski to Yokohama route. When the Arctic Tokyo is refurbished, it will be given a new name, **Madam Arctic**, and a new route.— Andy Brewington*

*In the photo above Captain Ken Fisher and Chief Officer Michael Smith are happy to receive the **Sealand Enterprise**'s fourth award for weather observations, but which spot will it occupy on the wall behind? Miami PMO Charles Henson makes*

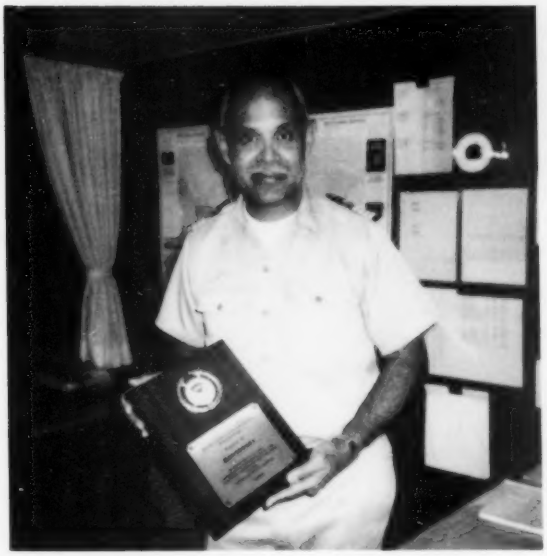
*the introductions and presents the VOS 1992 annual award to Master, Djuro Stanic . Henson awarded the M/V **Santa Paula** for the PMO of New Orleans, Jack Warrelmann. The **Santa Paula** was formerly the **Seward Bay**.*

PMO Jack Warrelmann, New Orleans, presents a company award to Billy Molero, Jr. Molero is the supervisor of the Chart & Radio Section of Lykes Brothers Steamship Co., Inc. (above left).

***Flemming Sif**'s Captain Erik Alex Houtved Poulsen accepts a VOS observing award from PMO Warrelmann (below, left). NOAA ship **Oregon II** in Pascagoula, MS was the scene for a VOS Weather Observation Award Ceremony (top, right).*

The happy recipients are 2nd Mate Jim Rowe in the center with Master Ted Kaiser to the right, PMO Jack Warrelmann stands to the left.

*Below, right PMO Warrelmann stands aboard the **Lash Atlantico** to present a VOS Observation plaque for outstanding weather observations in 1992. From left to right is Chief Mate Jed Sutter, Warrelmann, and Captain Scott Nowak.*



Captain D. Boellaard van Tuijl, M/V ***Monterrey,*** *accepts the VOS Weather Observation Award for 1992 from Bob Webster, PMO Los Angeles in photo above right. Again in Los Angeles, Bob presents a 1992 VOS award for the* ***Sea-Land Consumer*** *(below, left). Captain Peter Bailey is on the left and Chief Officer Kent Flick is on his right.*

Houston PMO Jim Nelson presents Capt. M.J.Bellamy of the mv ***Bibi*** *with a 1991 outstanding observation award in the form of pewter mugs and corduroy caps with the Canadian Marine Weather Observation logo (above right). In the photo below, right, Nelson gives a company award for outstanding support to Walter Kristiansen of Coastwise Trading Co. for continued weather observations from their fleet. Left to right are Jim Linn, Jim Nelson, Brian Teagher, Kristiansen, Rich Tammaro, Kim Redmann and Port Captain Phil Svede. As part of this effort, Jim's placed SEAS systems and full observation equipment on two of their vessels.*

Reporting Wave Information

Martin S. Baron
National Weather Service

Ship weather reports from the Southern Hemisphere are arriving at National Meteorological Centers distinctly later than Northern Hemisphere reports. Peak arrival times for North Atlantic, North Pacific, and Mediterranean Sea reports are in the H + 30 (30 minutes after report time) to H + 45 range. From the Indian and South Atlantic Oceans, peak arrivals are H + 60 or later! Please make every effort to improve the timeliness of Southern Hemisphere reports. Transmit your weather report as soon as possible after it's been coded. If you experience difficulties or delays from radio relay stations, please bring these to the attention of your PMO. Also please remember to fill out the section on communications difficulties in the back of the Ships Weather Observations form, WS Form B-81.

Mariners are all too familiar with the destructive power of waves and how their size and energy influences vessel operations. The Ship's Synoptic Code has one sea group (for wind driven waves) and three swell groups (for waves produced by distant wind). By including sea and swell information in your coded reports, you provide a tremendous service to fellow mariners and the entire marine community.

The four sea and swell groups are:

$2P_wP_wH_wH_w$–Sea Period, Height
$3d_{w1}d_{w1}d_{w2}d_{w2}$–True direction of primary and secondary swell
$4P_{w1}P_{w1}H_{w1}H_{w1}$–Period and height of primary swell
$5P_{w2}P_{w2}H_{w2}H_{w2}$–Period and height of secondary swell

Please note that sea wave direction is not reported– it is assumed to be the same as the wind direction (dd), reported in group Nddff. The direction of primary and secondary swell is the true direction from which the waves are coming. Select the appropriate code figure from *NWS Observing Handbook No. 1 (*NWSOH1) table 3.29 (at right).

Wave period is the time interval in seconds for successive crests or troughs to pass a given point. It is often convenient to choose a patch of foam and note the time required to go from one crest to the next. Record several oscillations and report the average period in seconds.

Wave height is the vertical distance from crest to adjacent trough, and wave systems always have waves of varying heights. Report the average height of the larger, better formed waves (significant wave height). Use the wave

Table 3.29 True Swell Wave Direction, in Tens of Degrees, $d_{w1}d_{w1}$, $d_{w2}d_{w2}$ (This code is also used for wind direction, dd. See p. 3-14.)

Code Figure	Direction	Code Figure	Direction
00	Calm	19	185° to 194°
01	5° to 14°	20	195° to 204°
02	15° to 24°	21	205° to 214°
03	25° to 34°	22	215° to 224°
04	35° to 44°	23	225° to 234°
05	45° to 54°	24	235° to 244°
06	55° to 64°	25	245° to 254°
07	65° to 74°	26	255° to 264°
08	75° to 84°	27	265° to 270°
09	85° to 94°	28	275° to 284°
10	95° to 104°	29	285° to 294°
11	105° to 114°	30	295° to 304°
12	115° to 124°	31	305° to 314°
13	125° to 134°	32	315° to 324°
14	135° to 144°	33	325° to 334°
15	145° to 154°	34	335° to 344°
16	155° to 164°	35	345° to 354°
17	165° to 174°	36	355° to 4°
18	175° to 184°	99	Direction indeterminate

Table 3.30 Code for Wave Height, H_wH_w, $H_{w1}H_{w1}$, $H_{w2}H_{w2}$. (The code is direct reading in units of half meters.)

Code	Meters	Feet	Code	Meters	Feet
00	< 0.5	< 1	15	7.5	24 or 25
01	0.5	1 or 2	16	8.0	26 or 27
02	1.0	3 or 4	17	8.5	28
03	1.5	5	18	9.0	29 or 30
04	2.0	6 or 7	19	9.5	31
05	2.5	8 or 9	20	10.0	32 or 33
06	3.0	10	21	10.5	34 or 35
07	3.5	11 or 12	22	11.0	36
08	4.0	13	23	11.5	37 or 38
09	4.5	14 or 15	24	12.0	39 or 40
10	5.0	16 or 17	25	12.5	41
11	5.5	18	26	13.0	42 or 43
12	6.0	19 or 20	27	13.5	44 or 45
13	6.5	21 or 22	28	14.0	46
14	7.0	23			

To obtain the code figures for heights over 46 feet, multiply the height in feet by 0.6, and round off the result to the nearest whole number.

height code table 3.30 in NWSOH1 (ar right).

The presence or absence of swell can sometimes be a useful weather forecasting tool. A threatening sky without any swell is usually indicative of short-lived bad weather, such as a thunderstorm, squall line, or weak frontal system. However, advancing and thickening storm clouds accompanied by increasing swell often suggests the approach of a major storm system with a large area of precipitation and strong winds.

New Recruits July–September 1993

During the 3-month period ending September 30, 1993, PMOs recruited a record 90 vessels as weather observers/reporters in the NWS VOS Program. Thank you for joining the VOS program.

Data shortages still persist from some areas and at certain reporting times. From the North Atlantic and North Pacific oceans, more observations are needed at 0600 and 1200 UTC. These are your late night/early morning reports—please make every effort to transmit them. More data is also needed from coastal waters, especially off the U.S. and Canadian west coasts, and from the Caribbean Sea. During the Northern Hemisphere hurricane season (May –November), reports from the tropics and the easterly trade wind belt (roughly 5°–35°N) are especially important. Data from the Southern Hemisphere (the South Atlantic, Indian, and South Pacific Oceans), is in particularly short supply. There is also a shortage of data from the Arctic Ocean.

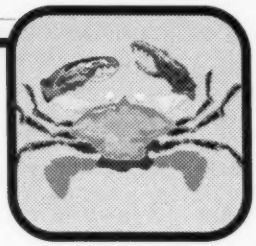
Coastal reports are extremely valuable, not only for the marine forecaster, but also for weather forecasts prepared for land areas near shore. Weather in the coastal zone can be very changeable and often moves inland. The forecaster needs all the information she can get. There is a 3-hourly reporting schedule in all United States and Canadian Coastal waters out 200 miles. Please comply with this schedule, time permitting.

NATIONAL WEATHER SERVICE VOLUNTARY OBSERVING SHIP PROGRAM
NEW RECRUITS FROM 01-JUL-93 TO 30-SEP-93

NAME OF SHIP	CALL	AGENT NAME	RECRUITING PMO
ABOU EL BARAKAT AL BARBARI	CNJB1	BASE NAVALE	NORFOLK, VA
ALBEMARLE ISLAND	C6LU3	ECUADORIAN LINES	NEWARK, NJ
ALMANIA	V2DH	US NAVIGATION INC.	NEWARK, NJ
ANAHUAC	ELQD2	TRANS. MARITIMA MEXICANA	JACKSONVILLE, FL
APJ SHALIN	VTNT	SURRENDRA OVERSEAS LTD.	LOS ANGELES, CA
ATLANTIC LILY	P3GC2	ATLANTIC LILY	MIAMI, FL
BOSBORUS BRIDGE	3FMV3	K-LINE AMERICA INC	SAN FRANCISCO,CA
BOVEC	J8EG7	STRACHAN SHIPPING CO.	LOS ANGELES, CA
BRAZILIAN REEFER	OXKP4	S. LAURITZEN A/S	BALTIMORE, MD
BURDUR	TCLN	D.B. DENIZ NAKLIYATI T.A.S./	N.Y., NY
BURSA	TCJX	STRACHAN SHIPPING CO INT.FIN..	N.Y., NY
CARIBE CARRIER	C6DS5	GREEN COVE MARITIME, INC	MIAMI, FL
CAROLINE OLDENDORFF	ELPS2	SUNRISE SHIPPING AGENCY	SEATTLE, WA
CCNI ANTARTICO	P3NP4	KERR STEAMSHIP CO	MIAMI, FL
CEDAR RUN (LCU-2010)	AADZ	329TH TRANSPORTATION COMPANY	N.Y., N.Y.
CEREZA ROSA	DVBF	PORT METEOROLOGICAL OFFICER	HOUSTON, TX
CHACABUCO	ELMO3	WIGHTMAN SHIPPING CO., INC	MIAMI, FL
CIUDAD DE MANTA	HCCM	ECUADORIAN LINE, INC	MIAMI, FL
DAPHNE	P3BT5	O.S.L. SHIPPING & DEV. INC.	NEWARK, NJ
DOLE CALIFORNIA	ELGH2	WILLIAMS DIMOND AND CO.	LOS ANGELES, CA
EIBE OLDENDORFF	ELOG8	NORTON LILLY & CO INC.	SEATTLE, WA
ELENORE	ELPR7	NORTON LILLY & CO. PANAMA	MIAMI, FL
ENCHANTED SEAS	3FMF2	S/S ENCHANTED SEAS	NEW ORLEANS, LA
ERICKSON ARCTIC	C6IB4	REDERIAKTIEBOLAGET G. ERIKSON	MIAMI, FL
FLORIDAY RESPONDER	WB08586		MIAMI, FL
FREJA ISLANDIA	C6JQ7	FREJA TANKERS	MIAMI, FL
FREJA SVEA	C6IK8	FREJA GROUP, FREJA TANKER A/S	N.Y., N.Y.
GREAT HARVEST	H3XU	WAH TUNG SHIPPING AGENCY	MIAMI, FL
HAKUFU	3EPJ5	NYK LINE NORTH AMERICA INC	SEATTLE, WA
HANDY ACCORD	DUXW	NYK LINE NORTH AMERICA INC	SEATTLE, WA
HUAL ROLITA	LAUY2	UGLAND MARITIME SERVICES	JACKSONVILLE,FL IBN
AL-ATHEER	HZLD	KERR STEAMSHIP CO. INC.	HOUSTON, TX
IOWA TRADER	KNDM	PENN-ATTRANSCO CORPORATION	HOUSTON, TX
ITB GROTON	KMJL	SHERIDAN TRANS. CO.	NEWARK, NJ
KAREN ANDRIE	WBS5272	MR. STAN ANDRIE	CHICAGO, IL
KARINA	A8WL	ZODIAC MARITIME AGENCIES LTD	NEW ORLEANS, LA
KOREAN PEACE	D8OE	PORT METEOROLOGICAL OFFICER	HOUSTON, TX
LIBERTY SEA	KPZH	LIBERTY MARITIME CORP.	NEW ORLEANS, LA
LT PRAGATI	VVDX	MYERS GROUP (US)	SEATTLE, WA
LTG WILLIAM B. BUNKER	AAEF	1099TH TRANSPORTATION DETACH.	N.Y, NY
LYRA	WSDG	LYKES BROTHERS SS CO	SAN FRANCISCO,CA
M/V BURSA	TCTX	STRACHAN SHIPPING COMPANY	N.Y., NY
MAERSK JEDDAH	BLHL	MAERSK LINE	SEATTLE, WA
MAERSK SANTIAGO	DGHL	UNIVERSAL MARITIME SERVICE	MIAMI, FL
MALAKAND	AQOL	T. PARKER HOST OF MARYLAND	BALTIMORE, MD
MT TIMUR MERCURY	C6KH4	THOME SHIP MANAGEMENT PTE.	N.Y., NY

NATIONAL WEATHER SERVICE VOLUNTARY OBSERVING SHIP PROGRAM
NEW RECRUITS FROM 01-JUL-93 TO 30-SEP-93

NAME OF SHIP	CALL	AGENT NAME	RECRUITING PMO
MT. CABRIT	D5NE	HESS OIL VIRGIN OIL. CORP.	NORFOLK, VA
NELVANE	YJW27	BARBER SHIP MANAGEMENT LTD	NEWARK, NJ
POLAR EAGLE	ELPT3		LOS ANGELES, CA
POMEROL	KALC	CREST TANKERS INC	SAN FRANCISCO, CA
PRESIDENT VAN BUREN	WWPI	LYKES BROTHERS SS CO.	LOS ANGELES, CA
REGAL EMPRESS	C6LW2	INTERNATIONAL SHIPPING PARTNERS,INC	NYC, N.Y.
RUBIN U	DUPD	USUI KAIUN CO. LTD	BALTIMORE, MD
SAMUAL GINN	C6OB	CHEVRON SHIPPING CO	SAN FRANCISCO, CA
SAMUEL L. COBB	KCDJ		SAN FRANCISCO, CA
SAN JUAN	LALY2	RIISE SHIPPING INC	NEW ORLEANS, LA
SANTORIN 2	P3ZL4	GENERAL STEAMSHIP CORP	SEATTLE, WA
SCAN	WMDZ	AMERICAN OVERSEAS MARINE CORP.	SAN FRANCISCO, CA
SEA MARINER	J8FF9	JARDINE SHIP MANAGEMENT	MIAMI, FL
SEA RIVER JAMESTOWN	KIYO	EXXON SHIPPING CO	LOS ANGELES, CA
SEALAND PACER	KSLB	SEA-LAND SERVICE INC	NEWARK, NJ
SOKOLICA	ELIG5	DELAWARE VALLEY MARINE, INC.	BALTIMORE, MD
SOL DO BRASIL	ELAQ5	MARITIME SERVICES	MIAMI, FL
SOUTHERN PRINCESS	DUCF	K LINE AMERICA, INC.	NEWARK, NJ
ST. LUCIA	D5ND	HESS OIL VIRGIN ISLAND CORP.	NORFOLK, VA
STAR SKOGANGER	LASS2	STAR SHIPPING (NY) INC.	HOUSTON, TX
STOLT AQUAMARINE	ELEG4	STOLT NIELSEN	NEWARK, NJ
STOLT CONDOR	D5VF	STOLT-NIELSEN INC.	NEWARK, NJ
TABUK	HZLK	UNITED ARAB AGENCIES	NEWARK, NJ
USAV ALDIE	AADJ	329TH TRANS CO	N.Y., NY
USAV BRANDY STATION	AADU	329TH TRANS CO	N.Y., NY
USAV BRISTOE STATION	AADV	329TH TRANS CO	N.Y, NY
USAV BUENA VISTA	AADX	329TH TRANS CO	N.Y., NY
USAV CHICKAHOMINY	AAEA	329TH TRANS CO	N.Y.,NY
USAV CHICKASAW BAYOU	AAEB	329TH TRANS CO	N.Y., NY
USAV CHURUBUSCO	AAEI	329TH TRANS CO	N.Y., NY
USAV CONTRERAS	ADMM	329TH TRANS CO	N.Y., NY
USAV CORINTH	ADMN	329TH TRANS CO	N.Y., NY
USAV GEN.FS. BESSON, JR	AAEC	335TH TRANS DETACH	N.Y., NY
USAV HOBKIRK (LCU-2023)	ADMU	329TH TRANS CO	N.Y., NY
USAV KENNYSAW MOUNTAIN	AAEG	329TH TRANS CO	N.Y., NY
USAV MACON	AAEH	329TH TRANS CO	N.Y., NY
USAV PERRYVILLE	ADNF	329TH TRANS CO	N.Y., NY
USAV PORT HUDSON	ADNG	329TH TRANS CO	N.Y., NY
USAV RUNNEYMEDE	AADS	329TH TRANS CO	N.Y., NY
USCGC CUSHING	NOFR	USCGC CUSHING	NEW ORLEANS, LA
USNS HAYES	NRLW	COMMANDING OPFFICER	JACKSONVILLE, FL
USNS STALWART	NCJE	MILITARY SEALIFT COMMAND	NORFOLK, VA
VELMA LYKES	WLAH	LYKES BROTHERS SS CO	NEW ORLEANS, LA
YOHFU	3EPK5	NYK LINE NORTH AMERICA INC	SEATTLE, WA



All times unless noted are UTC (universal time) and all miles are nautical. For additional detail, tropical cyclones will be covered in the annual reports from the tropical cyclone centers around the world. The weather summaries are based upon the track charts and Northern Hemisphere Surface Charts as well as ship reports, and attempt to highlight the most significant ocean features each month. The track charts are provided by NOAA's National Meteorological Center. If an extratropical storm is particularly bad for shipping, we may designate it as the Monster of the Month. The Gale Tables provided by the National Climatic Data Center at Asheville, NC, have been expanded to include U.S. ships reporting winds of 34 knots or more.

North Atlantic Weather
April, May, and June 1993

April—Both the Icelandic Low and the Azores–Bermuda High were stronger than normal which led to fairly tight pressure gradients over the northern shipping lanes. This is usually an indication that winds along these routes are stronger than normal. Potent storms were more plentiful during the first half of the month.

In fact, the month opened with a deep 963–mb Low just south of Kap Farvel, Greenland dominating the weather scene from the Grand Banks to the Denmark St. At 0600 on the 1st, the ***Malla Artica*** ran into 48–kn easterlies near 60°N, 45°W. They also recorded a pressure of 981 mb. By 0000 on the 2nd, the ***Hofsjokull*** (51°N, 42°W) estimated winds of 52 kn from the west but there was no wave report. The ***Cumulus*** (59°N, 22°W) measured 40–kn east southeasterlies in 10–ft seas at 1000 while 2 hrs later the ***Frithjof*** (61°N, 29°W) was clobbered by 50–kn east southeasterlies while battling 30–ft seas.

The storm weakened over the 2nd and 3rd but lingered until it was absorbed by two other systems on the 6th. All three combined into a deepening 984–mb center. Just prior to this occurrence a Low, which had formed over northern Alabama on the 1st, deepened rapidly to 969 mb on the 4th as it crossed the 20th meridian just south of 55°N heading toward northern Scotland. At 2100 on the 4th, the ***Malla Artica,*** involved in the previous storm, reported 45–kn easterlies while battling 15–ft seas. The toughest conditions occurred on the 5th east of 15°W and north of 50°N. Winds were running at 40 to 60 kn while seas of 15 to 30 feet were being measured. The system moved across northern Scotland and into the North Sea on the 6th.

At the same time three centers were combing into a dangerous Low southeast of Kap Farvel. By 1200 on the 7th, its 958–mb center had slowed north of 55°N and was beginning to turn a clockwise loop. This did not bode well for North Atlantic traffic in the region. The ***Frithjof*** (64°N, 35°W) measured 42–kn northeasterlies in 17–ft swells at 1800 on the 7th, some 400 mi north of the center. The few reports available closer to the center indicated winds were at storm force (50 kn or more). The following day the ***Frithjof*** was reporting 23–to 26–ft seas. By the 9th, the storm completed its loop and was noticeably weaker. It fizzled as it meandered in an easterly direction.

During the next 3 weeks, several Lows caused intermittent problems but most were short–lived. Meanwhile the Azores–Bermuda High became more prominent and, in fact, from the 20th till the end of the month dominated a good portion of the

central North Atlantic. This forced cyclonic activity towards the North American coast and along the coast of western Europe.

Casualties—On the 8th, the 40-ft fv ***Michelle Lee*** at anchor 30 mi west of Crystal River, FL was overwhelmed by a breaking wave and sank. The three people in the fishing boat were able to launch a liferaft, but two of the three died from exposure before help arrived 3½ days later. On the 11th, the 88-ft British ketch ***Vanderdecken***, built in 1909, sustained heavy weather damage while enroute from St. Martin to Cuxhaven. The eight people on board were rescued and the vessel abandoned. The following day the ***Vishva Mohini*** sank in the Bay of Biscay, off the north coast of Spain, in stormy weather. Sixteen of the crew were rescued while twelve bodies were recovered and another twenty-one were missing and presumed dead. On the last day of the month, the 72-ft steel clam boat ***Gulf Air*** capsized in rough waters in Buzzards Bay. One fisherman died while two others were rescued.

May—The normally dominant Azores-Bermuda High suffered an intruder as a 1012-mb climatic Low was analyzed west of the Bay of Biscay this month. This is too far south to be called a misplaced Icelandic Low. This Iberian Low created pressure anomalies of -6 mb over a wide area of ocean. These anomalies were the result of a number of weak to moderate Lows cavorting over the Azores, England, and the Iberian Peninsula. Except for the indentation in the northeast sector, the Azores- Bermuda High was nearly normal.

During the first half of the month, several weak to moderate Lows made their way from off Kap Farvel through the Denmark St and into the Greenland Sea. One 976-mb Low stalled in the strait on the 4th and 5th. The ***OUEW*** was located some 150 mi north of the center on the 3rd and was reporting a 983-mb pressure with continuous snow. At time their visibility was 200 yds. Winds were hovering near storm force (50 kn) while seas were estimated at 15 to 30 ft. There wasn't much in the way of confirmation of these conditions although the ***TFTV*** (66°N, 28°W) estimated 70-kn winds in snow showers at 2100 on the 4th. The Low finally continued northeastward late on the 5th and weakened rapidly. By the 9th, a large 1038-mb High centered over the Norwegian Sea extended over the British Isles and south of Iceland temporarily protecting these waters. Another large High was centered over the mid-North Atlantic with a third along the mid-Atlantic coast of the U.S.

A 990-mb Low was centered near 40°N, 40°W at 1200 on the 12th. The pressure gradient west of and close to the center was tight enough that several vessels were reporting gale force winds. The ***British Renown*** (37°N, 43°W) ran into 50-kn northwesterlies at 0600 on the 12th. In general winds were being measured at 40 to 45 kn although ***Mayview Maersk*** measured 49-kn west northwesterlies in 33-ft seas at 1800 on the 12th. On the 12th, the Low made a radical northward jog followed by a return to the south the following day. It passed just north of the Azores on the 15th as a 994-mb Low. On the 16th it became part of a larger circulation with another center at 989 mb over northern Scotland. The system finally organized into one single center just west of Ireland on the 18th. It deepened to 978 mb that same day but headed in a northwesterly direction. It was generating winds in 40 to 50-kn range. The ***C6HD5*** measured a 54-kn southwesterly near 48°N, 6°W at 2200 on the 18th. ***Tower 62125*** (54°N, 4°W) confirmed this with a measured 55-kn south southwesterly in 17-ft seas. On the 19th at 1200, the ***FPPF*** (52°N, 14°W) ran into 53-kn southwesterlies in 8-ft swells, but the storm was already starting to dissipate.

About this time there was an odd occurrence which contributed significantly to the climatic Iberian Low. A rather weak system was making its way eastward along the 55th parallel from the 19th to 21st. It stalled and became part of a complex system which established itself over the northeastern North Atlantic with a primary center west of the Bay of Biscay. Central pressure was in the 990-mb range and winds were only in the 20- to 30-kn range. The center meandered to a position off the coast of Portugal on the 26th as it was blocked on all sides by high pressure areas. On the 27th, a total of four centers could be recognized with the dominant one just west of the English Channel. It wasn't until the 29th that this amorphous mass organized into a compact circulation with a 986-mb center southwest of Ireland. It moved slowly across Great Britain as the month came to a close.

Casualties—In the Mediterranean on the 2nd, the dredger ***Bouhairet Tunis,*** while being towed from Gabes to Tunis, sank near Kerkennah Is in bad weather. On the 3rd about 12 mi south of Worthing (English Channel), the tanker

Apache collided with the mv ***Birte Wehr*** in dense fog. The 62-ft yacht ***Ocean Vagabond*** sank in an Atlantic storm while sailing from Bermuda to the Azores. The five people on board were picked up from a life raft by the yacht ***Zuno***. On the 16th, the refrigerated mv ***Gran Piedra*** was adrift 5 mi south of Bishop Rock in Force 6–8 winds, rough seas, heavy swells, and poor visibility in the rain. The crew of 13 was rescued and the ship taken in tow before it drifted into the Isle of Scilly. In the Azores at Corvo Is the mfv ***Landana*** was forced aground by winds and waves after it lost its rudder. The crew abandoned the vessel by means of a wire rope connected to the ship from the shore.

June—The Icelandic Low made an unexpected appearance this month northeast of Newfoundland. Remnants are normally visible around southern Greenland, but this climatic feature was more compact and well south of where it would be expected. It reflected a flurry of cyclonic activity; mostly weak low pressure systems, tracking between Newfoundland and Iceland.

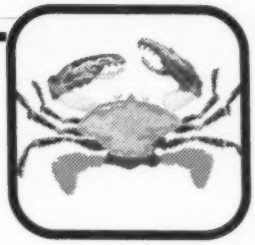
The month opened with a a pair of 990-mb Lows, one west of the British Isles and another over mid-ocean. Also the first North Atlantic tropical depression was spotted just north of Cuba. The British Low was responsible for some gale force winds mainly south and west of its center. The ***Professor Mierzejewski*** (48°N, 17°W) was belted by 42-kn westerlies in 13-ft seas at 12000 on the 1st while 6 hrs later the ***KRPD*** (47°N, 15°W) ran into 46-kn westerlies while battling 25-ft. swells. This storm weakened on the 2nd while the other Low survived and headed northeastward, but was not much of a weather factor.

This Low made the trip from Colorado to Norway over a 2-week beginning on the 6th. It crossed Lake Superior as a 993-mb Low on the 9th and entered the North Atlantic off Nova Scotia late on the 10th. The ***Hubert Gaucher*** (48°N, 60°W) reported a 51-kn southwesterly at 1200 on the 10th. This was an isolated report. At 1800 on the 12th, the ***DHFW*** (43°, 42°W) hit a 45-kn westerly. By this time the storm had a 989-mb center which was crossing the 50th parallel near 38°W. The system continued to intensify slightly and by the 14th central pressure had dipped to 984 mb. Reports from vessels such as the ***Leonard J. Cowley***, ***Newfoundland Otter*** and the ***Atlantic Conveyor*** were indicating that winds were running 40 to 45 kn with seas in the 10-to 15-ft range. The eastward moving system began to weaken as it moved south of Iceland and across northern Scotland. However, it did manage to maintain its identity as it swung east northeastward into southern Norway late on the 19th.

During the second half of the month, a number of high pressure systems became established forcing the relative weak Lows that did form toward the Denmark St. There was very little activity over the northeastern North Atlantic and from the Bay of Biscay to the Norwegian Sea. The most active region, cyclonically, was from the Gulf of St. Lawrence to the Denmark St.

A large double-centered Low organized on the 24th with one center off Nova Scotia and a second northeast of Newfoundland. This combination in conjunction with a large High to the southeast created enough of a gradient to generate some strong winds and rough seas particularly along the shipping routes to Mediterranean ports. Caught up in the associated front, the ***C6HD59*** (39°N, 55°W) ran into 50-kn west northwesterlies at 2100 on the 24th. Between the double-centered Low and the 1030-mb High, winds were blowing out of the southwest at about 20 to 30 kn with swells running 10 to 20 ft. This was a fairly static situation for several days until finally the Lows split—one dissipated while the other organized into a small 992-mb system on the 27th. This storm moved northeastward and briefly intensified into a 982-mb Low at the southern end of the Denmark St on the 28th at 1200. However, the system began to weaken as it slowly made its way through the strait.

Casualties—The 738-ft. Liberian-flagged freighter ***Minerva***, fully laden with petroleum coke, ran aground outside the Sabine Pass just as Tropical Storm Arlene began to hammer the Texas coast. On the 3rd, the 15,649—ton tanker ***British Trent*** collided with the ***Western Winner*** in fog off Ostend, Belgium. The gasoline—laden tanker ignited a blaze which engulfed the ship killing nine crewmen in this English Channel tragedy. By some accounts flames reached 100 ft. The bulk carrier, ***Canadian Olympic,*** downbound ran into foggy conditions in the West Neebish Channel of St. Mary's River. The carrier was apparently making a left turn into the Rock Cut approach when the bow ploughed into the river bottom. The entire river was closed to shipping 15 min later due to fog.



North Pacific Weather
April, May, and June 1993

April– While the subtropical high was nearly normal for April, the Aleutian Low was about 10 mb stronger than usual and reminiscent of February. A few potent Lows contributed significantly to this climatic anomaly.

The month opened with a 959-mb Low from March centered near 53°N, 170°W dominating the northern shipping lanes. At 0000 on the 1st, the ***Sanko Prelude*** (45°N, 171°W) was measuring 48-kn westerlies in 25-ft swells. Gales were being reported out to 700 mi southwest and south of the center. The system moved east northeastward and slowly began to fill.

Another system came to life over Honshu on the 11th. This Low intensified slowly during its first few days as it moved eastward then swung toward the northeast. An explosive deepening took place from 1200 on the 13th to 1200 on the 14th when central pressure fell from 987 mb to 960 mb– a drop of 27 mb in 24 hrs. By the 14th the storm had begun an eastward trek. The deepening was reflected in a report by the ***Oriental Highway*** (46°N, 174°W). At 0000 on the 14th, they were measuring 41-kn southerlies in 17-ft swells; 3 hrs later winds were at 58 kn. At this same time, the ***Rubin Forest*** (50°N, 179°E) was belted by 57-kn northeasterlies. Storm force winds were common during this period, but the ***Rubin Forest*** was sending in reports every 3 hrs, an effort that kept forecasters well apprised of this storm's intensity.

Like several previous storms, however, this intensity was relatively short-lived. By 1200 on the 15th, the central pressure was up to 976 mb, still a good spring storm but a lot less dangerous. It was slowly combining with a system in the Gulf of Alaska and by the 16th there were actually three separate centers with a large circulation that covered a good portion of the northeastern North Pacific. Even on the 15th, there were reports of storm force winds from the ***Maren Maersk*** (44°N, 143°W) and gales were common. Eventually, the system became a single-centered 980-mb Low over the Gulf of Alaska.

While the previous system was fading over the Gulf of Alaska, another fairly potent Low was coming to life south of Tokyo on the 17th. Moving toward the northeast, the center deepened from 996 mb on the 17th to 976 mb 24 hrs later. By the 20th it was at 972 mb crossing the central Aleutians and recurving toward the north and eventually west. At 1500 on the 18th, the ***Henry Hudson Bridge*** (40°N, 164°E) just southwest of the center measured 46-kn westerlies and a 986-mb pressure. The ***President Polk*** (36°N, 169°E) battled 20-ft seas in 42-kn winds at 1200. The general conditions continued to distract mariners on the 19th and 20th, but the storm was well into the Bering Sea by the 21st.

The remainder of the month was fairly quiet although several moderate Lows flared up briefly, causing some local problems over the northern shipping routes.

Casualties– On the 15th, the 42-ft charter fishing boat ***Rain Song*** capsized in 15- to 20-ft seas within 400 yds of shore while crossing the bar into Yaquina Bay, OR. Two passengers were reported missing and one body was found. Twelve others were rescued by the Coast Guard. On the 22nd, the mv ***Condor***, enroute for Japan had engine failure and listed 30°. The weather was too rough to lower life boats.

The crew was rescued by a patrol boat and the vessel was eventually taken in tow.

May—The Aleutian Low is usually barely recognizable in May, but this year it had a 1006-mb center and its circulation extended along the entire length of the Aleutians into the Gulf of Alaska and northeastern North Pacific. This resulted in negative anomalies as much as -10 mb in regions where the subtropical high is normally dominant. The subtropical high was forced slightly to the southwest of its normal position. The track chart for May shows a large number of extratropical cyclones and most were weak to moderate system. The frequency was the most significant factor in the resurrection of the Aleutian Low.

The month opened with a 976-mb Low in the Gulf of Alaska which was generating 40- to 45-kn winds in 10- to 20-ft seas. Reporting ships included the ***Henry Hudson Bridge***, ***Emma Oldendorff***, ***NODX***, and the ***President Polk***. On the 3rd, this system was replaced by a 970-mb Low from the southwest and so strong winds and rough seas continued. The ***Overseas Joyce*** (43°, 173°W) at 0000 on the 3rd gave an early indication of this storm's potency when it reported 53-kn southwesterlies in 10-ft seas and 26-ft swells. Several other vessels in the southwest quadrant suffered storm force winds as well. The ***Anders Maersk*** sent in a series of good reports during the several days that this system constituted a threat to shipping. For example, at 1200 on the 4th near 45°N, 163°W, they estimated winds at 40 kn from the west in seas of 20 ft. with 26-ft swells. These storms made for an inauspicious start to a late spring month. The second storm moved into the Gulf of Alaska and it was gradually replaced by another system on the 6th, which was not quite as potent.

At 0000 on the 8th, a storm, which had developed south of Tokyo just 2 days before, briefly intensified near 40°N, 160°E. Its central pressure dipped to 968 mb at this time and ships in the vicinity were feeling the sting of 40- to 45-kn winds and 10- to 20-ft seas. At 0000 on the 9th, the ***OCL Exporter*** (40°N, 164°E) encountered a 48-kn westerly in 20-ft. swells. While it filled as it moved northeastward, the storm's central pressure remained in the 980-mb range until the 11th when it moved over the Alaska Peninsula.

The next storm of any significance meandered east of the Kamchatka Peninsula for about a week and was most potent from the 12th through the 14th. During this period vessels in the area were reported 40- to 45-kn winds in 10- to 15-ft swells. After a large counterclockwise loop, this system ended up over Kamchatka on the 18th.

The daily weather charts for the next several weeks showed a plethora of low pressure centers strung out across the North Pacific and on the 18th Tropical Storm Jack popped up near Eniwetok Atol in the Marshall Is. Jack moved westward but was quickly downgraded to a tropical depression. The frequent but weak cyclonic activity continued to dominate the North Pacific until the end of the month.

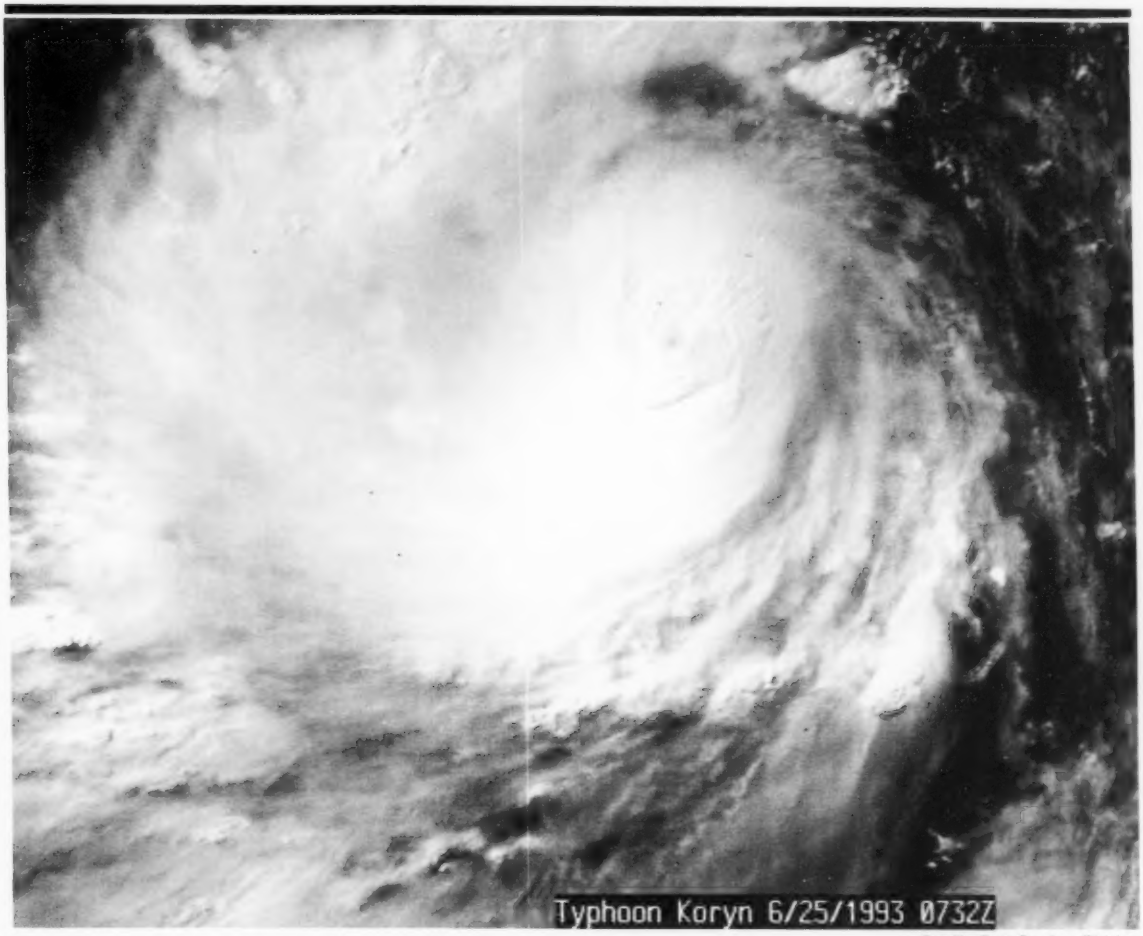
Casualties— On the 19th, the cargo ship ***White Hakuyo*** collided with the ***Shusei Maru*** in dense fog about 4.7 mi. off Saganoseki, Japan.

On the 26th, in the southern hemisphere off South Africa, helicopters rescued 16 crew members from the sinking 37,000-ton bulk carrier Nagos. The vessel had taken on water when the hatch blew off in rough seas and high winds. The crew members were adrift in two life rafts some 70 mi south of Port Elizabeth. However, it was reported that 17 crew members including, the captain, perished.

On the 11th, some 30 mi. off the coats of Washington, a fisherman from the 61-ft ***Lihue III*** was swept from the deck by a wave. A second crew member jumped into the 8-ft seas to swim the victim back to the boat. Unfortunately, the rescuer suffered a heart attack and died.

June—The climatic scene was fairly normal this month as the subtropical high dominated a good portion of the North Pacific. The Aleutian Low which is usually barely noticeable was even less so this month. The major weather feature in June was Typhoon Koryn.

The first significant storm to influence weather over the shipping lanes was a 974-mb Low centered over 50°N, 163°W at 0000 on the 5th. This system had originated in late May east of Tokyo and moved into June as a 1004-mb system heading eastward. On the 2nd, it began a gradual turn toward the northeast. It crossed the 45th parallel near 166°W just after 1200 on the 4th as a 990-mb system. By this time it had started making waves. An excellent report was received at 0600 from the ***Sea-Land Spirit*** (41°N, 168°W). They measured 41-kn southerlies in 13-ft seas while visibility was down to 2 mi in rain showers. Six



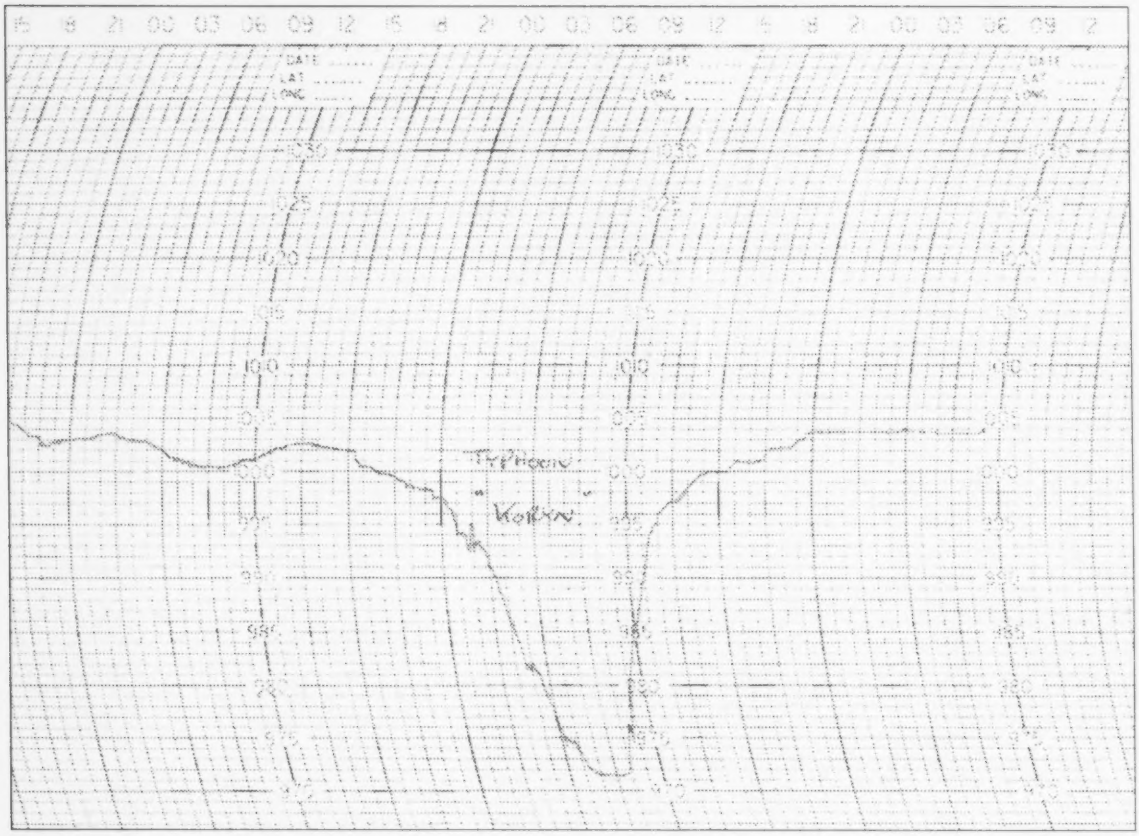
Satellite Data Services Division

Typhoon Koryn roams the western North Pacific in late June. Koryn first hit the northeast coast of Luzon and then battered Hong Kong. On the following page the ***Anders Maersk*** *enroute from Singapore to Hong Kong took the measure of Koryn with a nice looking barogram trace. The trace bottomed out at about 971 mb.*

hrs later their winds were up to 45 kn and swells were 17 ft. At 0000 on the 5th, the ***British Adventure*** (46°N, 162°W) ran into 45-kn west southerlies in 20-ft seas. The ***Thomas G. Thompson*** (46°N, 157°W) was belted by 18-ft seas in 42-kn southerlies at 0600 on the 5th. The storm was reaching its peak. This was attested to by the ***Iron Kembla*** (51°N, 155°W) at 1200 which reported a measured 52-kn southwesterly and 6 hrs later was braving 30-ft swells. They continued to battle these conditions into the 6th. By this time, the 982-mb storm had reached Kodiak Island where it turned a counterclockwise loop and continued to weaken. It was tracked across the Gulf of Alaska and finally moved inland over the Alexander Archipelago on the 10th.

A series of weak Lows and several high pressure systems dominated the weather across the North Pacific from the 10th through the 18th. During that period Hurricane Adrian in the eastern North Pacific and Typhoon Koryn in the west made their initial appearances.

This is a tale of two storms. One formed on the 21st east of Honshu and the other developed over Tokyo on the 23rd. The Tokyo storm moved on a smooth parabolic track and intensified slowly. The other Low moved northward to the Kamchatka Peninsula and then on the 22nd its 984-mb center turned abruptly toward the east southeast. It followed a sine wave track and ended up meeting and merging with the

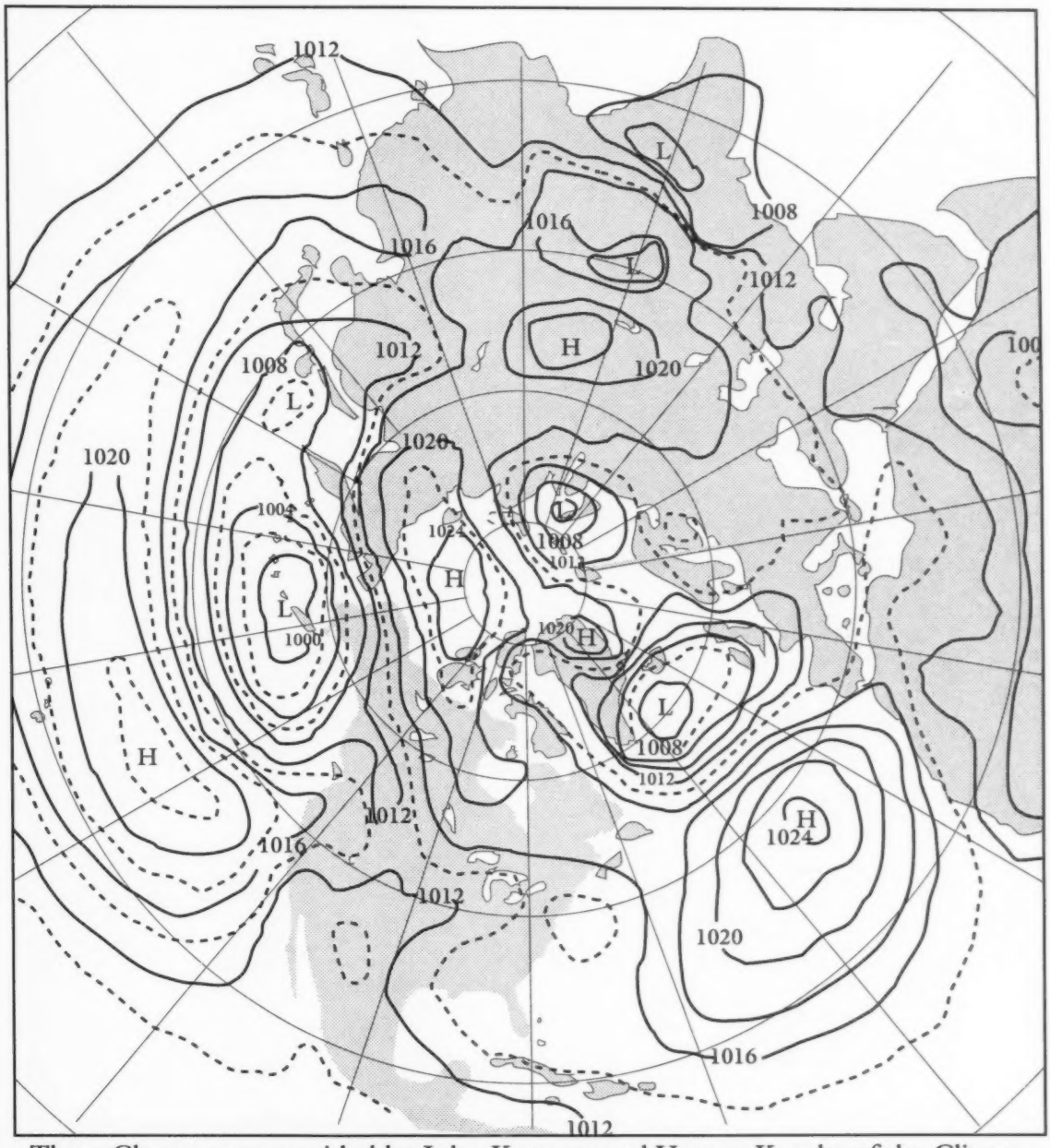


Tokyo storm on the 25th near 48°N and the dateline. This energized 980-mb Low headed north northeastward into the Bering Sea. At 0000 on the 25th, the ***3ELW4*** (54°N, 175°W) measured a 41-kn south southeast wind in 7-ft swells. At 0000 on the 27th, the ***BKHH*** (54°N, 170°W) ran into 40-kn southwesterlies. By this time, the 984-mb center was off Nunirak Island in the Bering Sea, where it meandered until the month's end.

Casualties—On the 26th Typhoon Koryn, packing 100-kn winds, slammed into the northeast coast of Luzon killing at least seven people and unleashing mudflows which forced more than 18,000 people to flee for their lives. The typhoon then proceeded to batter Hong Kong. Rescue helicopters from the colony plucked 24 survivors from 45-ft swells on the 27th as the mv ***Lian Gang*** sank 70 mi southeast of Hong Kong. The British captain and three crew members died. The mv ***Lara Mikheyenko*** had engine trouble and was rolling up to 45° after snapping a rudder. The vessel recovered. The mv ***Belinetta*** took on water about 2 mi east of Baili Island on the 27th. The vessel was finally beached on the island and all crew stayed ashore during the typhoon. Numerous other vessels in Hong Kong and Manila either dragged their anchors or were driven aground by the weather.

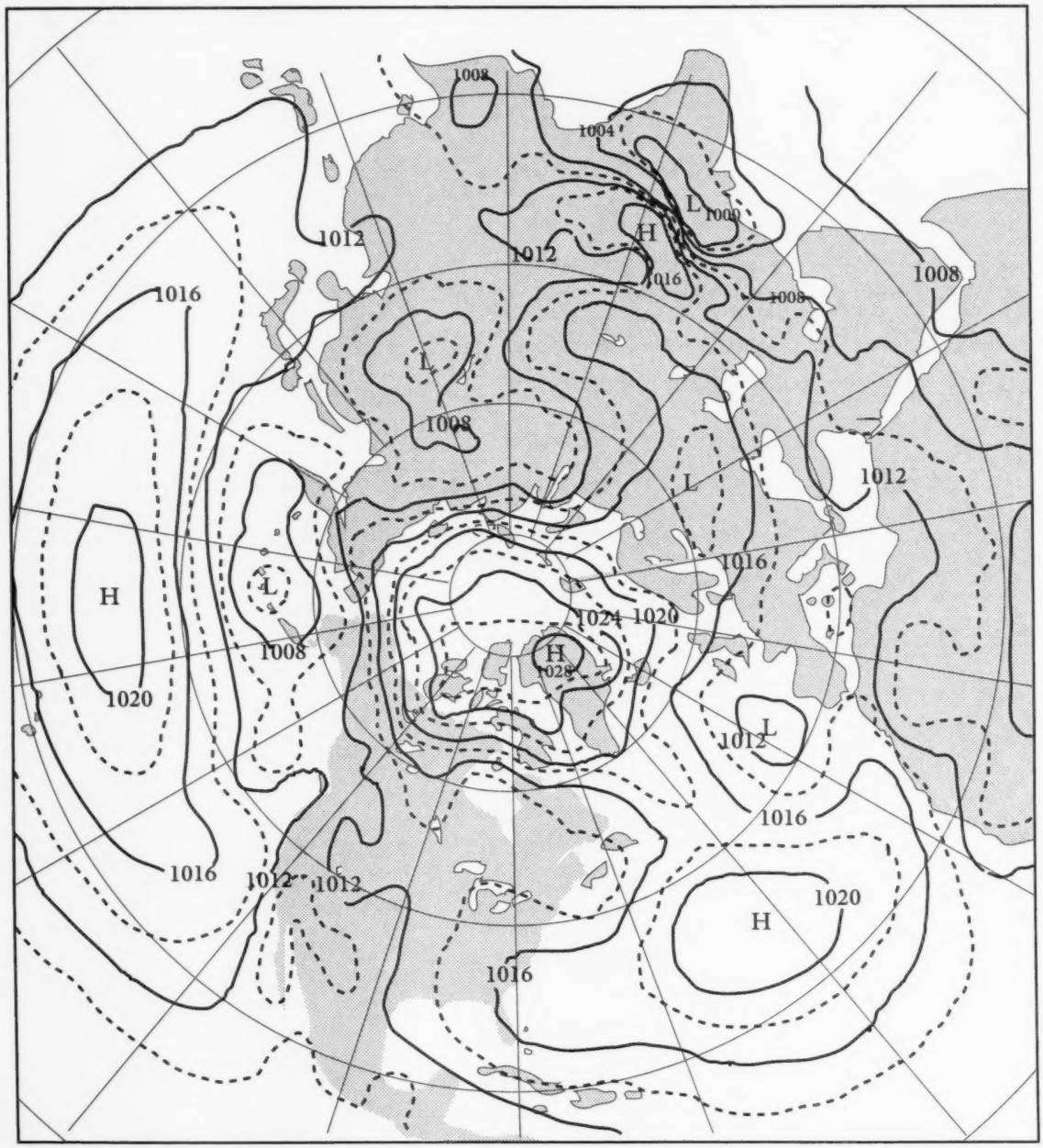
On the lst, the sand carrier ***Seisho Maru No. 18*** sank in heavy seas in the Busan area. On the 15th, the ***Nichiwa Maru***, a vehicle carrier sank following a collision with the ***Windward*** in fog near 34.5°N, 138.9°E; the crew was rescued. Toward the end of the month the 360-ft Norwegian tanker ***Betula*** broke loose from its tug and drifted aground on the Pacific coast of Mexico. Over time the vessel ruptured and leaked an estimated 4,400 tons of sulfuric acid and 150 tons of fuel oil near Playa Azul.

April 1993



These Charts were provided by John Kopman and Vernon Kousky of the Climate Analysis Center from the Climate Diagnostics Bulletin

May 1993



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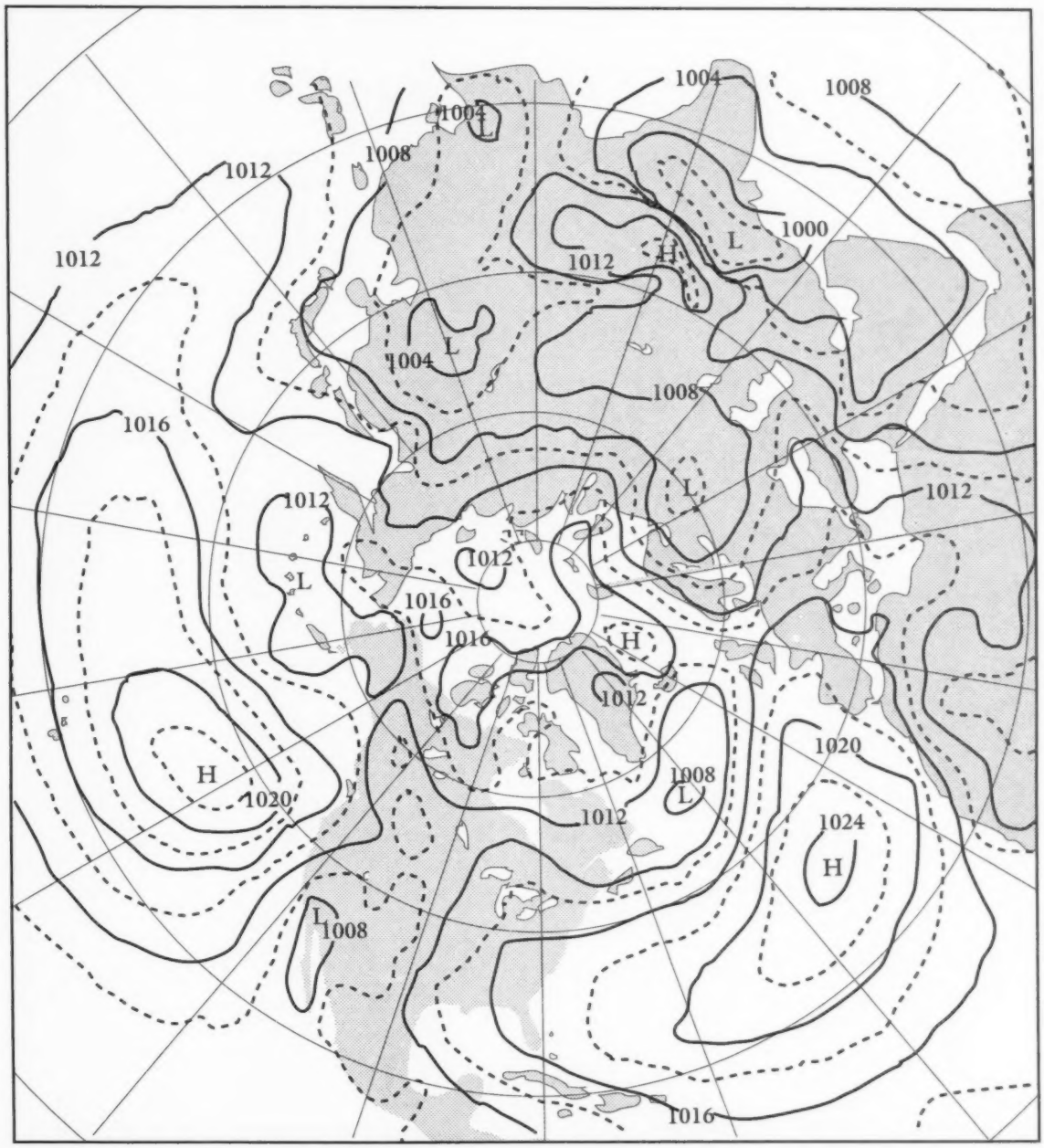
June 1993



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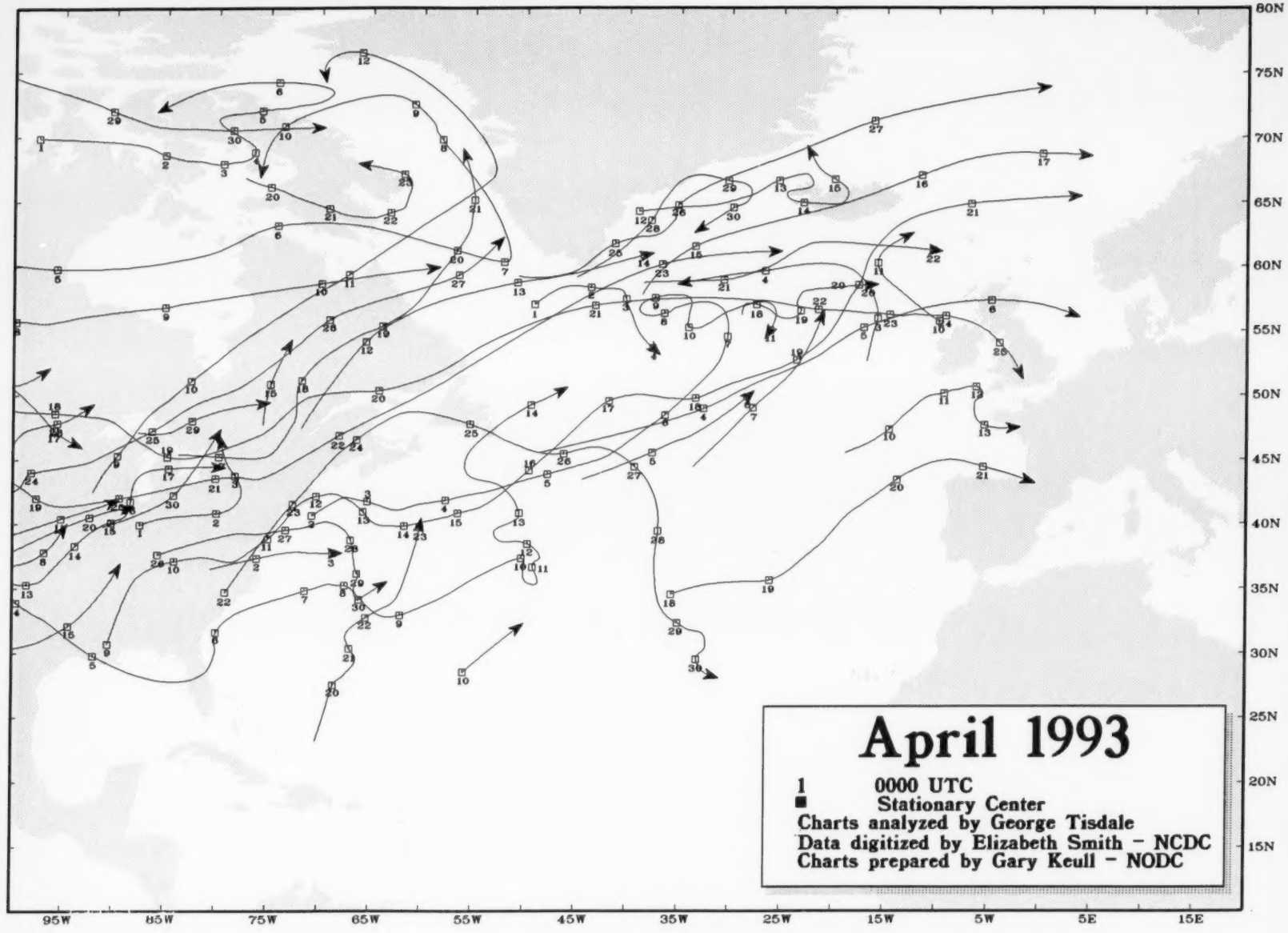
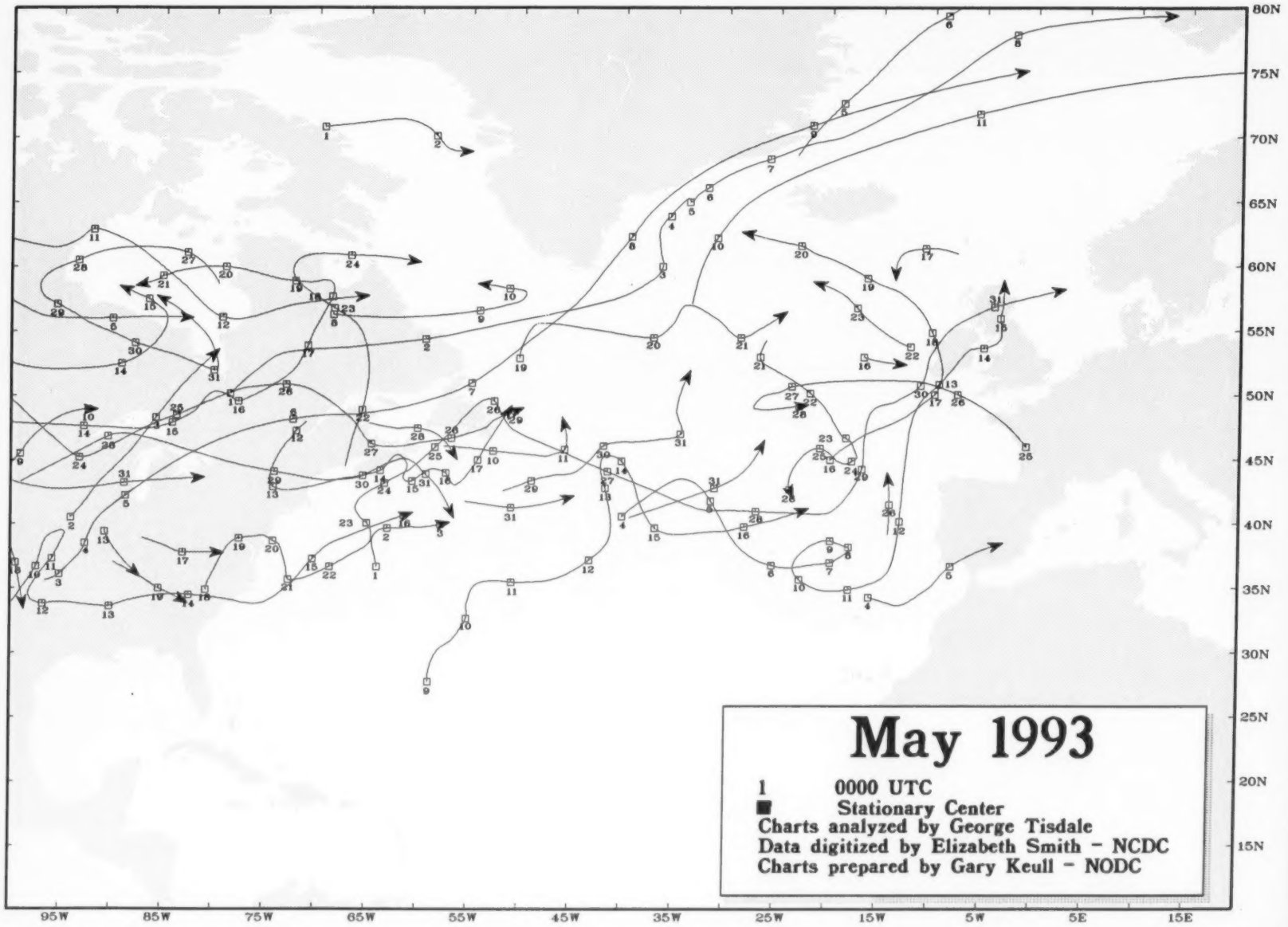
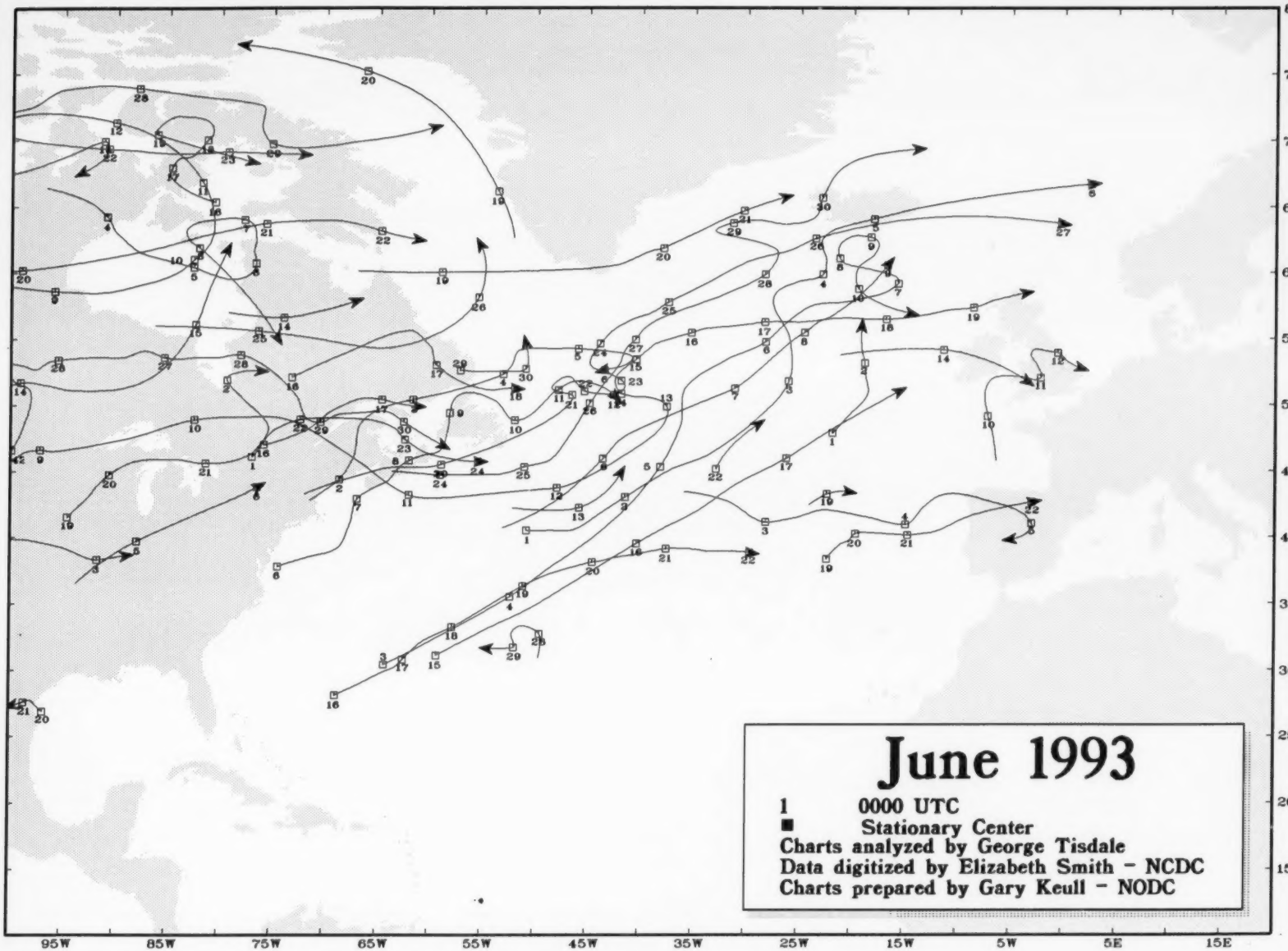
Principal Tracks of Cyclone Centers at Sea Level, North Atlantic



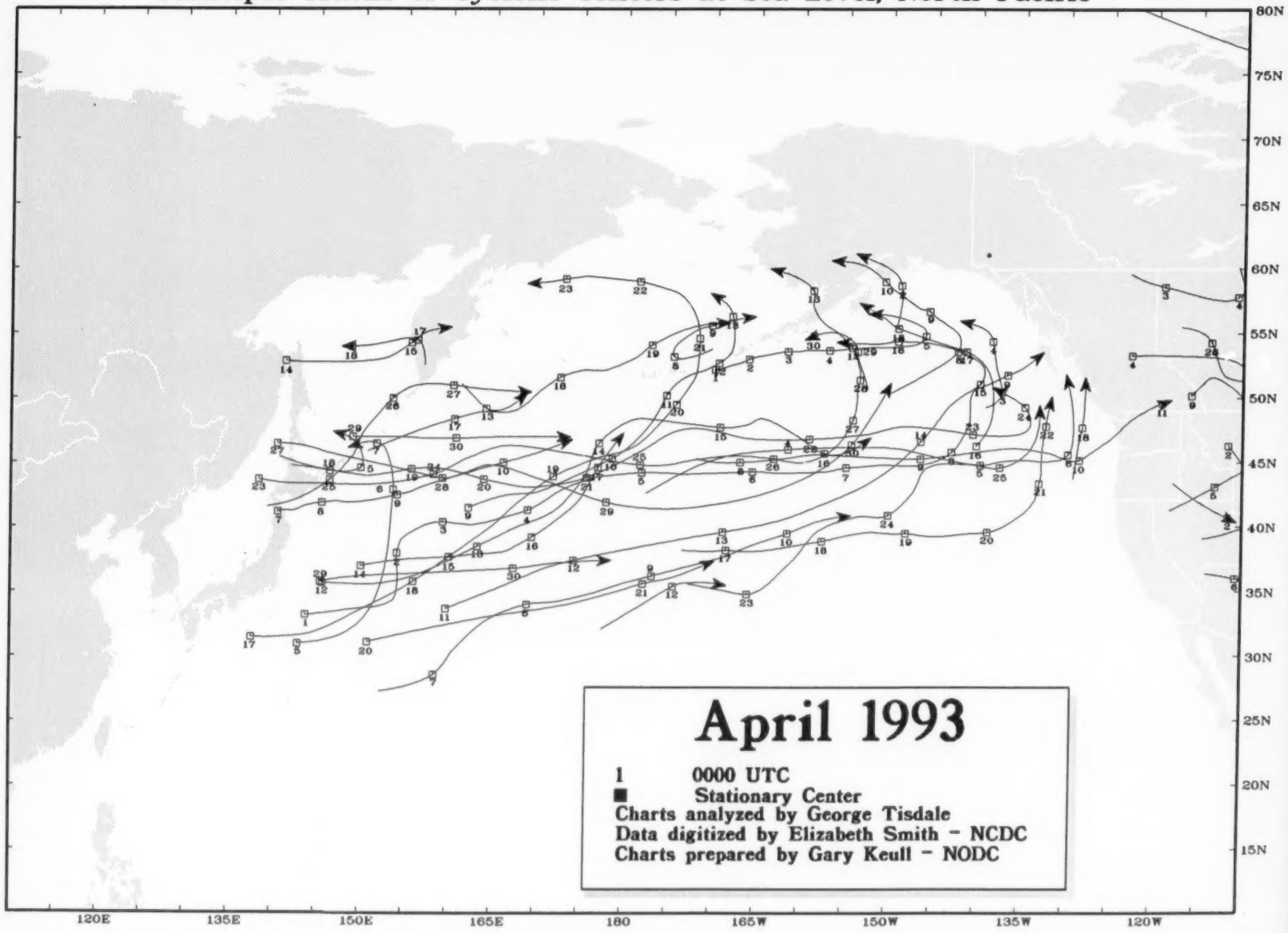
Principal Tracks of Cyclone Centers at Sea Level, North Atlantic



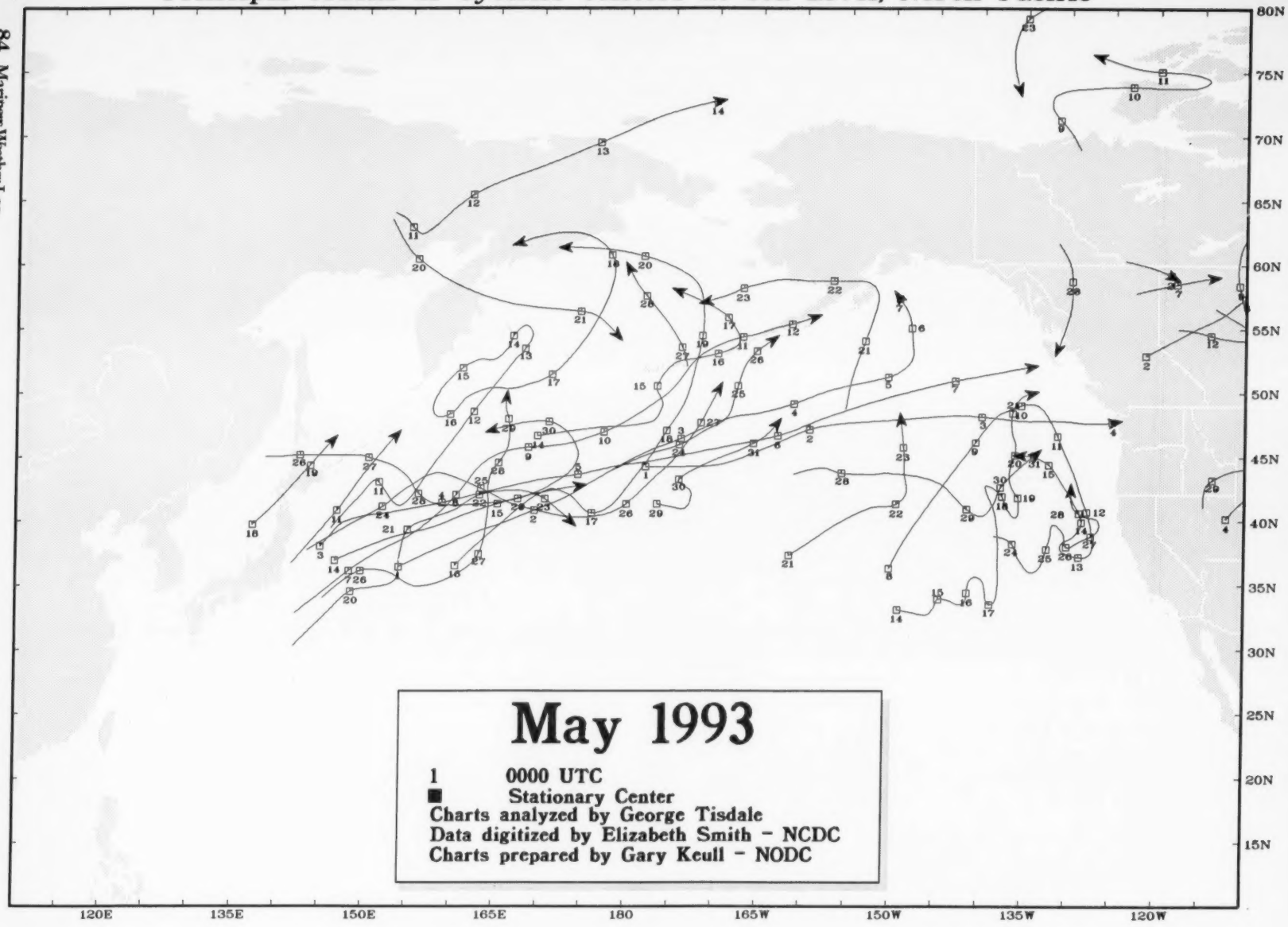
Principal Tracks of Cyclone Centers at Sea Level, North Atlantic



Principal Tracks of Cyclone Centers at Sea Level, North Pacific



Principal Tracks of Cyclone Centers at Sea Level, North Pacific



May 1993

1 0000 UTC

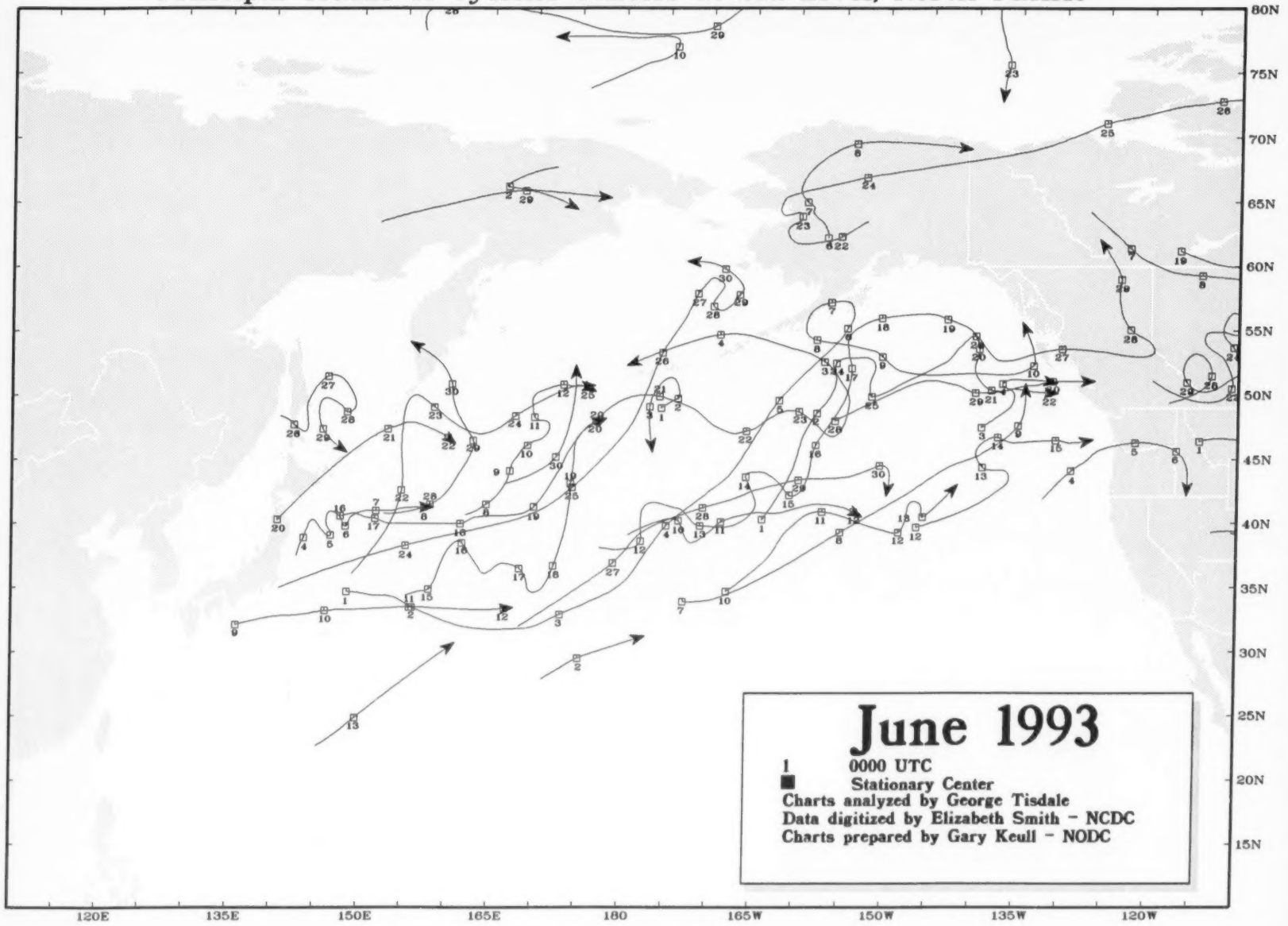
■ Stationary Center

Charts analyzed by George Tisdale

Data digitized by Elizabeth Smith - NCDC

Charts prepared by Gary Keull - NODC

Principal Tracks of Cyclone Centers at Sea Level, North Pacific



April, May and June 1993

	RADIO	MAIL
1ST LT ALEX BONNYMAN	60	131
1ST LT BALDOMERO LOPEZ	9	
1ST LT JACK LUMMUS	74	71
2ND LT. JOHN P. BOBO		7
A. V. KASTNER	153	
ACADIA FOREST	105	115
ACE ACCORD	21	23
ACONCAGUA	34	
ACT 7	219	
ACT I	127	
ADABELLE LYKES	62	132
ADAM E. CORNELIUS	11	27
ADRIAN MAERSK		14
ADVANTAGE	33	85
AFRICAN CAMELLIA	1	62
ALASKA RAINBOW	75	55
ALBERT MAERSK	12	33
ALBERTO TOPIC	8	47
ALDEN W. CLAUSEN	5	8
ALLIGATOR COLUMBUS	47	39
ALLIGATOR EXCELLENCE	60	
ALLIGATOR FORTUNE	23	22
ALLIGATOR GLORY	47	121
ALLIGATOR HOPE	100	173
ALLIGATOR JOY	37	14
ALLIGATOR LIBERTY	94	
ALLIGATOR PRIDE	36	54
ALLIGATOR TRIUMPH	49	53
ALMANIA	2	71
ALMERIA LYKES	58	36
ALPENA	230	105
ALTAMONTE	35	34
AMER HIMALAYA	10	
AMERICA STAR	152	
AMERICAN CONDOR	46	37
AMERICAN CORMORANT	32	24
AMERICAN FALCON	64	32
AMERICAN KESTREL	4	
AMERICAN MARINER	60	27
AMERICAN VETERAN	21	
AMERICANA	70	18
AMERIGO VESPUCCI	27	63
AMULET	75	74
ANDERS MAERSK	49	175
ANNA MAERSK	22	103
APJ SHALIN	38	59
ARABIAN SENATOR	121	
ARCO ALASKA		31
ARCO ANCHORAGE	32	24
ARCO CALIFORNIA		46
ARCO FAIRBANKS	26	48
ARCO SAG RIVER		24
ARCO SPIRIT	2	64
ARCO TEXAS	24	17
ARCTIC OCEAN	162	130
ARCTIC TOKYO	51	153
ARGONAUT	50	99
ARILD MAERSK	50	
ARMCO	75	77
ARNOLD MAERSK	1	22
AROSIA	2	
ARTHUR M. ANDERSON	111	116
ARTHUR MAERSK		202
ASHLEY LYKES	22	64
ASIAN SENATOR	192	
ASPEN	11	
ASTERIKS	24	94
ATIGUN PASS	4	9
ATLANTA BAY	18	
ATLANTIC CARTIER	53	
ATLANTIC COMPASS	102	
ATLANTIC CONVEYOR	81	
ATLANTIC OCEAN	21	56
ATLANTIS II	41	
ATLAS HIGHWAY	11	22
AUSTRAL RAINBOW	22	33
AXEL MAERSK	21	129
AYA II	32	
B.T. ALASKA	58	63
BAAB ULLAH	1	
BALTIC SUN	71	
BALTIMORE TRADER	94	168
BARBARA ANDRIE	106	162
BAY BRIDGE	114	116
BEBEDOURO	58	
BIBI	155	
BLUE HAWK	11	
BLUE RIDGE	39	105
BOB L	5	
BOGASARI LIMA	264	72
BOHOL SAMPAGUITA	30	
BONN EXPRESS	72	
BOVEC	19	74
BP ADVENTURE	80	
BRIDGETON	61	69
BRIGIT MAERSK	29	
BROOKLYN BRIDGE	147	89
BROOKS RANGE	42	21
BRUCE SMART	11	140
BUCKEYE	207	206
BUFFALO	2	
BURNS HARBOR	413	466
CALCITE II	74	79
CALIFORNIA CARRIER	45	
CALIFORNIA CERES	83	
CALIFORNIA HERMES	73	33
CALIFORNIA LUNA	53	
CALIFORNIA ORION	78	82
CALIFORNIA PEGASUS	64	
CALIFORNIA STAR	169	
CALIFORNIA TRITON	72	24
CALIFORNIA ZEUS	60	
CANADIAN LIBERTY	14	19
CAPE HUDSON	32	
CAPE MAY	157	
CARINA	44	134
CARLA A. HILLS	44	69
CARMEL	32	58
CARNIVALE	32	23
CAROLINA	30	90
CARTAGENA	148	
CASON J. CALLAWAY	248	242
CASSIA	34	
CATHAY SPIRIT	65	
CEDRELA	44	20
CELEBRATION	48	62
CELTIC LIGHT	1	
CENTURY HIGHWAY #2	131	231
CENTURY HIGHWAY NO. 5	227	
CGM LORRAINE	18	
CGM PROVENCE	20	
CHARLES B. RENFREW	1	
CHARLES LYKES	29	85
CHARLES M. BEEGHLEY	73	45
CHARLES PIGOTT		38
CHARLESTON	32	16
CHARLOTTE LYKES	50	130
CHC NO.1	12	
CHELSEA	6	
CHEMICAL PIONEER	117	136
CHERRY VALLEY	39	22
CHESAPEAKE TRADER	104	113
CHESTNUT HILL	44	29
CHEVRON ANTWERP	39	
CHEVRON BURNABY	41	126
CHEVRON COLORADO	31	42
CHEVRON COPENHAGEN,MON		119
CHEVRON EDINBURGH	94	245
CHEVRON FELUY		120
CHEVRON HORIZON		29
CHEVRON MISSISSIPPI	69	76
CHEVRON PACIFIC	84	177
CHEVRON STAR		68
CHEVRON SUN		123
CHEVRON WASHINGTON	120	155
CHIQUITA BOCAS	30	
CHIQUITA CINCINNATION	85	148
CHIQUITA ITALIA	85	
CHIQUITA JEAN	155	
CHOAPA	36	
CIELO DI FIRENZE	13	19
CLEMENTINA	11	
CLEVELAND	55	70
COAST RANGE	17	30
COASTAL CORPUS CHRISTI	20	6
COASTAL EAGLE POINT	11	
COASTAL MANATEE	36	30
COLIMA		11
COLLEEN SIF	171	180
COLUMBIA BAY	59	
COLUMBIA STAR	367	191
COLUMBUS AMERICA	372	
COLUMBUS AUSTRALIA	72	
COLUMBUS NEW ZEALAND	165	
COLUMBUS OHIO	31	
COLUMBUS OLIVOS	20	
COLUMBUS QUEENSLAND	159	
COLUMBUS VICTORIA	192	
COLUMBUS VIRGINIA	176	
COLUMBUS WELLINGTON	206	
COMPANION EXPRESS	87	
CONCERT EXPRESS	72	
CONTIENTAL WING	63	
CONTSHIP AUSTRALIA	75	
CORAH ANN	94	75
CORNUCOPIA	42	92
CORONADO	5	8
CORPUS CHRISTI	136	169
CORWITH CRAMER	71	
COURIER	49	
COURTNEY BURTON	116	117
COURTNEY L.	98	168
CPL. LOUIS J. HAUGE JR		2
CRISTOFORO COLOMBO	35	61
CROWN PRINCESS	96	68
CSL INNOVATOR	62	
CSS HUDSON	122	
DAN MOORE	2	
DEL MONTE CONSUMER		66
DEL MONTE TRADER	102	221
DELAWARE TRADER	135	161
DIANA	12	31
DIRECT FALCON	115	39
DIRECT KEA	246	
DIRECT KIWI		157
DIRECT KOOKABURRA	139	188
DOCTOR LYKES	124	116
DON JORGE	5	9
DOUBLE GLORY	8	
DSR BALTIC	116	
DSR EUROPE	107	
DSR OAKLAND	98	
DSR YOKOHAMA	77	
DUSSELDORF EXPRESS	129	
DYVI BALTIC	16	44
DYVI OCEANIC	79	
E.P. LE QUEBECOIS	473	
EASTERN GLORY	17	
ECSTASY	132	164
EDGAR B. SPEER	220	236
EDWARD L. RYERSON	139	174
EDWIN H. GOTT	405	432
EDYTH L.	90	128
ELIZABETH LYKES	40	15
ELLEN KNUDSEN	43	30
EMERALD SEA	58	48
EMMA OLDENDORFF	119	74
ENDEAVOR 2	27	64
EQUALITY STATE	1	
ESPERANCE	10	
ESSO PALM BEACH	16	36
ESSO PUERTO RICO	8	
EUROPEAN SENATOR	53	
EVER GAINING	14	
EVER GATHER	5	50
EVER GENTLE	5	
EVER GENTRY	10	
EVER GIANT	17	14
EVER GIVEN	12	7
EVER GLAMOUR	20	13
EVER GLORY	17	
EVER GOODS	19	69
EVER GRADE	19	

	RADIO	MAIL
EVER GROUP	14	15
EVER GROWTH	5	
EVER GUARD	25	16
EVER GUEST		4
EVER GUIDE	3	
EVER LAUREL	31	
EVER LEVEL	10	7
EVER LOADING	2	
EXPORT FREEDOM	48	84
EXPORT PATRIOT	53	156
EXXON BATON ROUGE	29	2
EXXON BENICIA	22	19
EXXON CHARLESTON	15	
EXXON MEDITERRANEAN	12	2
EXXON NEW ORLEANS	18	6
EXXON NORTH SLOPE	8	14
EXXON PHILADELPHIA	4	
EXXON SAN FRANCISCO	18	32
FAIRLIFT	93	
FANTASY	62	30
FARNELLA	15	
FAUST	59	55
FEDERAL SKEENA	165	142
FERNCROFT	109	56
FESTIVALE	22	
FETISH	92	105
FIR GROVE	25	
FOREST HAWK	81	
FOREST KING	62	
FRANCES HAMMER	136	160
FRANCES L.	72	35
FRANCOIS DE SALE	30	13
FRED G.	33	39
FRED R. WHITE JR	107	111
GALVESTON BAY	106	68
GEMINI,USA	12	15
GENEVIEVE LYKES	4	12
GEORGE A. SLOAN	43	40
GEORGE A. STINSON	52	45
GEORGE H. WEYERHAEUSER	33	18
GEORGE SHULTZ		26
GEORGE WASHINGTON BRID	176	23
GEORGIA RAINBOW II	46	31
GERMAN SENATOR	14	
GERONIMO	4	
GLACIER BAY	35	
GLOBAL LINK	17	24
GLORIOUS SPICA	40	
GOLDEN APO	22	
GOLDEN BEAR	102	140
GOLDEN GATE	9	
GOLDEN GATE BRIDGE	196	
GOLDEN MONARCH	28	
GREAT LAND	193	307
GREEN BAY	64	24
GREEN HARBOUR	65	118
GREEN ISLAND	34	73
GREEN KOBE	33	155
GREEN LAKE	113	167
GREEN RIDGE	100	95
GREEN SAIKAI	1	
GREEN SASEBO	52	184
GREEN SUMA	44	142
GREEN VALLEY	20	28
GUANAJUATO	60	81
GUAYAMA	7	7
GULF SPEED	79	
GYPSUM BARON	142	
GYPSUM KING	127	
H. LEE WHITE	175	137
HANEI SKY	5	24
HANJIN CHUNGMU	39	
HANJIN ELIZABETH	11	
HANJIN FELIXSTOWE	10	
HANJIN HAMBURG	11	
HANJIN HONG KONG	50	
HANJIN KAOHSIUNG	3	
HANJIN KEELUNG	24	
HANJIN KOBE	37	
HANJIN LE HAVRE	14	
HANJIN LONG BEACH	41	
HANJIN MASAN	15	
HANJIN NEW YORK	28	
HANJIN OAKLAND	11	8
HANJIN ROTTERDAM	14	5
HANJIN SAVANNAH	41	
HANJIN SEATTLE	7	
HANJIN VANCOUVER	11	
HANJIN YOKOHAMA	23	
HANSA LUBECK	145	
HANSA VISBY	23	
HEIDELBERG EXPRESS	127	
HENRY HUDSON BRIDGE	162	
HERBERT C. JACKSON	50	40
HERMENIA	31	44
HESIOD	3	
HIBISCUS	38	82
HOEGH CAIRN	11	
HOEGH CLIPPER	2	
HOEGH DRAKE	19	
HOEGH DUKE	7	
HOEGH DYKE	41	29
HOEGH MINERVA	29	45
HOLIDAY	88	24
HONESTA	78	
HOWELL LYKES	81	32
HUAL ANGELITA	46	105
HUAL INGRITA	11	
HUAL TRAPPER	3	
HUMACAO	75	160
HUMBER ARM		9
HYUNDAI COMMANDER	3	
HYUNDAI CONTINENTAL	47	
HYUNDAI DUKE	41	
HYUNDAI NO. 1	18	
IBN AL-MOATAZ	33	
INDEPENDENT ACCORD	198	
INDEPENDENT SPIRIT	178	
INDIAN GOODWILL	1	
INDIAN OCEAN	12	21
INDIANA HARBOR	151	197
INFANTA	179	
INGER	43	95
ISABELLA	20	54
ISLAND PRINCESS	21	
ITB BALTIMORE	79	73
ITB NEW YORK	82	113
ITB PHILADELPHIA	22	38
IVER EXPLORER	36	
IVER EXPRESS	17	
J. DENNIS BONNEY		254
J.L. MAUTHE	42	
J.W. POWELL	64	
JACKSONVILLE	93	102
JAHRE SPIRIT	58	
JALAGOPAL	3	
JALISCO	60	77
JAMES LYKES	25	93
JAMES R. BARKER	245	182
JAPAN CARRYALL	11	
JAPAN RAINBOW 2	71	15
JAPAN SENATOR	94	
JAVAVIHAR,INDIA	17	27
JEAN LYKES	70	91
JEB STUART	7	4
JO ROGN	64	
JOHN G. MUNSON	288	7
JOHN J. BOLAND	155	134
JOHN LYKES	30	
JOHN V. VICKERS	113	93
JOHN YOUNG		61
JOSEPH H. FRANTZ	221	198
JOSEPH L. BLOCK	107	142
JUBILANT	30	23
JUBILEE	20	24
JULIUS HAMMER	83	58
JUPITER	55	
KAIMOKU	185	189
KAINALU	174	163
KAKUSHIMA	14	11
KAUAI	117	209
KAYE E. BARKER	168	129
KEE LUNG	34	24
KEISHO MARU	54	
KELVIN CHALLENGE	104	
KENAI	123	139
KENNETH E. HILL	19	60
KENNETH T. DERR	75	111
KEYSTONE CANYON	82	78
KEYSTONER	21	81
KITTANING	1	
KOKUA	9	12
KOKUA,USA		60
KOLN ATLANTIC	110	
KOPER EXPRESS	14	
KURE	14	
LA TRINITY		9
LADY MARYLAND		16
LAKE CHARLES	4	9
LAKE GUARDIAN	73	49
LASH ATLANTICO	24	4
LAUST MAERSK	27	135
LAWRENCE H. GIANELLA	18	39
LEONARD J. COWLEY	52	
LEONIA	81	
LERMA	20	
LESLIE LYKES	62	93
LETITIA LYKES	32	19
LIBERTY BELLE	40	89
LIBERTY SPIRIT	17	25
LIBERTY STAR	45	16
LIBERTY SUN	58	111
LIBERTY VICTORY	146	214
LIBERTY WAVE	34	10
LION OF CALIFORNIA	20	9
LIRCAY	101	98
LNG AQUARIUS	17	109
LNG CAPRICORN	26	53
LNG LEO	43	58
LNG TAURUS	17	98
LNG VIRGO	25	54
LOA	83	4
LONGAVI	91	71
LONTUE	33	
LOUISE LYKES	14	22
LT ARGOSY	25	
LT. ODYSSEY	33	
LUNA MAERSK	18	35
LURLINE	72	178
M. P. GRACE	1	
M/S SEVEN OCEAN,PHILIP	22	40
M/V LIBERTY SEA,USA		50
MAASSLOT	109	
MAASSTROOM	203	
MACKINAC BRIDGE	176	51
MADISON MAERSK	15	98
MAERSK BOGOTA	8	
MAERSK CONSTELLATION	77	96
MAERSK SANTIAGO	113	120
MAERSK SUN	8	
MAERSK TACOMA	9	
MAGIC	81	
MAGLEBY MAERSK	32	79
MAJ STEPHEN W PLESS MP	13	41
MAJESTIC MAERSK	7	72
MANILA BAY	23	
MANILA EXPRESS	63	72
MANILA SUNRISE	19	45
MANUKAI	68	171
MANULANI	85	121
MARCHEN MAERSK		15
MAREN MAERSK	21	104
MARGARET LYKES	33	71
MARGRETHE MAERSK	64	87
MARIE MAERSK	48	97
MARIF	22	41
MARINE PRINCESS	18	61
MARINE RELIANCE	17	
MARIT MAERSK	36	54
MARJORIE LYKES	43	41
MARLIN		186
MASON LYKES	35	78
MATHILDE MAERSK	23	95
MATSONIA	53	181
MAURICE EWING		49
MAYAGUEZ	85	138
MAYVIEW MAERSK	50	93
MC-KINNEY MAERSK	2	65
MEDALLION	47	21
MEDUSA CHALLENGER	291	274
MELBOURNE HIGHWAY	4	
MELBOURNE STAR	61	
MELVILLE	116	160
MERCANDIAN CONTINENT	20	16
MERCANDIAN SUN II	36	40
MERCURY ACE	89	
MERIDA	98	59
MESABI MINER	113	86
METTE MAERSK	23	70
MICHIGAN	237	248
MICHIGAN HIGHWAY	12	
MICRONESIAN COMMERCE	31	

	RADIO	MAIL
MICRONESIAN INDEPENDEN	36	15
MICRONESIAN PRIDE	48	
MIDDLETOWN	26	36
MING PEACE	15	
MING PLENTY	50	26
MING PROMINENCE	11	
MING PROPITIOUS		138
MING PROSPERITY	21	31
MITLA	65	170
MOANA PACIFIC	137	
MOANA WAVE	94	
MOKU PAHU	152	241
MONTE CERVANTES	115	
MONTERREY	104	77
MORELOS	119	63
MORMACSKY	12	41
MORMACSTAR	54	100
MORMACSUN	85	88
MYRON C. TAYLOR	163	172
MYSTIC	107	
NACIONAL SANTOS	1	
NAPIER STAR	1	
NARA	69	
NATAL	16	14
NATIONAL DIGNITY	32	24
NATIONAL HONOR	25	67
NATIONAL PRIDE	28	28
NCC ARAR	12	19
NECHES	4	
NEDLLOYD HOLLAND	58	113
NEDLLOYD MAAS	36	
NEDLLOYD MADRAS	9	
NEDLLOYD MANILA	79	
NEDLLOYD MARSEILLS	93	
NEDLLOYD ROTTERDAM	104	
NEDLLOYD TOKYO	28	
NEDLLOYD VAN CLOON	110	
NEDLLOYD VAN DIEMEN	73	
NEDLLOYD VAN LINSCHOTE	74	
NEDLLOYD VAN NOORT	76	
NEPTUNE ACE	20	
NEPTUNE AMBER	13	
NEPTUNE AZURITE	34	
NEPTUNE CORAL	33	
NEPTUNE CRYSTAL	43	
NEPTUNE DIAMOND	140	
NEPTUNE GARNET	48	
NEPTUNE JADE	34	
NEPTUNE PEARL	21	
NEVA, PANAMA		51
NEVERSINK	496	
NEW HORIZON	128	165
NEW YORK SENATOR	14	
NEWARK BAY	65	141
NIPPON HIGHWAY	8	
NOAA DAVID STARR JORDA	201	57
NOAA SHIP ALBATROSS IV	226	286
NOAA SHIP CHAPMAN	335	358
NOAA SHIP DELAWARE II	298	351
NOAA SHIP DISCOVERER O	199	212
NOAA SHIP FERREL	7	
NOAA SHIP M. BALDRIDGE	440	
NOAA SHIP MCARTHUR	17	19
NOAA SHIP MILLER FREEM	401	447
NOAA SHIP MT MITCHELL	41	305
NOAA SHIP OREGON II	447	360
NOAA SHIP RAINIER	226	
NOAA SHIP SURVEYOR	74	8
NOAA SHIP T. CROMWELL	44	478
NOAA SHIP WHITING	361	438
NOBEL STAR	77	29
NORGAS VICTORY	1	
NORWAY	24	20
NOSAC EXPRESS	22	
NOSAC FOREST	155	
NOSAC RANGER	82	117
NOSAC ROVER		12
NOSAC TAKAYAMA	9	
NUEVO SAN JUAN	80	99
NURNBERG ATLANTIC	81	
NYK STARLIGHT	67	
NYK SURFWIND	25	
OAXACA	153	141
OBO ENGIN	51	23
OCEAN BRIDGE	1	
OCEAN CHEER	32	
OCEAN CONQUEROR	13	29
OCEAN EXPLORER	42	57
OCEAN HIGHWAY	47	
OCEAN SPIRIT	26	
OCEAN VICTOR	13	35
OLEANDER	156	170
OLIVE ACE	83	47
OMI CHARGER	17	59
OMI MISSOURI	66	
OMI WABASH	2	
OOCL BRAVERY	49	
OOCL EDUCATOR	52	28
OOCL ENVOY	97	43
OOCL EXECUTIVE	71	82
OOCL EXPLORER	98	155
OOCL EXPORTER	103	
OOCL FAIR	122	90
OOCL FAITH	99	
OOCL FIDELITY	112	56
OOCL FORTUNE	133	25
OOCL FREEDOM	84	
OOCL FRIENDSHIP	26	
OOCL INNOVATION	46	66
OOCL INSPIRATION	120	162
ORANGE BLOSSOM	45	89
ORANGE STAR	17	37
ORCHID	18	13
OREGON RAINBOW II	49	104
OREGON STAR	165	
ORION HIGHWAY	110	81
OURO DO BRASIL	35	
OVERSEAS CHICAGO	45	153
OVERSEAS HARRIET	29	50
OVERSEAS JOYCE	70	43
OVERSEAS JUNEAU		88
OVERSEAS MARILYN	35	50
OVERSEAS NEW ORLEANS	81	93
OVERSEAS NEW YORK	77	182
OVERSEAS OHIO	12	16
OVERSEAS PHILADELPHIA		108
PACASIA	33	
PACDUKE	32	
PACIFIC EMERALD	80	
PACIFIC PRINCESS	81	
PACKING	25	
PACMERCHANT	56	
PACNOBLE	4	
PACOCEAN	35	
PACPRINCE	32	
PACPRINCESS	63	2
PACQUEEN	40	12
PACSEA	27	
PACSTAR	27	
PACTRADER	29	
PAPAGO	63	11
PAPYRUS	15	
PATRICIA RICKMERS		92
PATRIOT	114	
PAUL BUCK	26	23
PAUL H. TOWNSEND	188	91
PAUL R. TREGURTHA	303	214
PAUL THAYER	40	29
PC EXPLORER	16	54
PECOS	40	47
PEGGY ANN	10	10
PERMEKE	64	139
PETER W. ANDERSON	80	61
PETROBULK PROGRESS	100	
PFC DEWAYNE T. WILLIAM	8	
PFC EUGENE A. OBREGON	27	34
PFC JAMES ANDERSON JR	87	103
PFC WILLIAM B. BAUGH	11	26
PHAROS	42	
PHILIP R. CLARKE	117	129
PHOENIX DIAMOND	17	
PIERRE FORTIN	465	
PLATTE		15
POLAR ALASKA	13	83
POLYNESIA	139	115
PRESIDENT ADAMS	101	129
PRESIDENT ARTHUR	16	59
PRESIDENT BUCHANAN	24	38
PRESIDENT EISENHOWER	125	171
PRESIDENT F. ROOSEVELT	116	175
PRESIDENT GARFIELD	3	
PRESIDENT GRANT	90	155
PRESIDENT HARDING	87	
PRESIDENT HARRISON	104	
PRESIDENT HOOVER	46	125
PRESIDENT JACKSON	160	155
PRESIDENT JEFFERSON	30	102
PRESIDENT KENNEDY	125	107
PRESIDENT LINCOLN	122	202
PRESIDENT MONROE	155	133
PRESIDENT POLK	185	207
PRESIDENT TRUMAN	129	193
PRESIDENT TYLER	54	150
PRESIDENT WASHINGTON	183	119
PRESQUE ISLE	219	139
PRIDE OF BALTIMORE	44	75
PRINCE OF OCEAN	91	236
PRINCE OF TOKYO	87	170
PRINCE OF TOKYO 2	62	211
PRINCE WILLIAM SOUND	19	95
PRINSENGRACHT	182	
PRODUCT SPLENDOR	8	
PROFESOR MIERZEJEWSKI	3	
PROSPERO	3	
PVT FRANKLIN J. PHILLI	50	52
PYTCHLEY	152	
QUEEN ELIZABETH 2	142	
R. HAL DEAN	82	90
R.J. PFEIFFER	144	167
RAINBOW HOPE	15	111
RAINBOW WARRIOR	51	
RALEIGH BAY	71	134
RANGER	4	
RANGER III	38	39
RANI PADMINI	68	
RECIFE	244	95
REFORM	29	
REGAL EMPRESS	5	21
REGAL EMPRESS, PANAMA	1	6
RESERVE	82	110
RESOLUTE	50	70
RICHARD G MATTIESEN	38	50
RICHARD REISS	43	46
ROBERT E. LEE	18	35
ROGER BLOUGH	56	118
ROSETTA	37	34
ROSINA TOPIC	21	134
ROTTERDAM	58	
ROVER	116	116
ROWANBANK	87	
ROYAL PRINCESS	88	
RUBIN DOGA	37	
RUBIN FOREST	67	198
RUBIN OCEAN	26	4
RUTH LYKES	46	65
S.T. CRAPO	189	135
S/S HUMACAS, USA		12
S/S POTOMAC, USA		5
SABINE		5
SALINA CRUZ PILOTS	320	168
SALINAS	16	41
SAM HOUSTON	28	35
SAMUEL H. ARMACOST	122	195
SAMUEL L. COBB	42	36
SAN LUIS	64	
SAN MARCOS	113	125
SAN MARTIN	166	
SAN PEDRO	28	
SANKO PRELUDE	27	13
SANTA BARBARA	36	
SANTA PAULA	89	118
SANTOS	11	
SATURN DIAMOND	43	
SAVANNAH	3	
SCARAB	44	
SEA BELLS	18	155
SEA COMMERCE	43	
SEA FAN	79	158
SEA FORTUNE	21	41
SEA FOX	45	12
SEA ISLE_CITY	12	80
SEA LIGHT	24	34
SEA LION	315	335
SEA MERCHANT	268	148
SEA SPRAY	4	
SEA TRADE	7	
SEA WOLF	229	144
SEABOARD HORIZON	2	
SEABOARD OCEAN	24	100
SEALAND ACHIEVER	140	136
SEALAND ANCHORAGE	67	138
SEALAND ATLANTIC	129	146
SEALAND CHALLENGER	50	77

	RADIO	MAIL
SEALAND CONSUMER	175	196
SEALAND CRUSADER	138	88
SEALAND DEFENDER	69	
SEALAND DEVELOPER	55	112
SEALAND DISCOVERY	22	1
SEALAND ENDURANCE	54	35
SEALAND ENTERPRISE	208	229
SEALAND EXPEDITION	47	62
SEALAND EXPLORER	92	125
SEALAND EXPRESS	81	165
SEALAND HAWAII	222	247
SEALAND INDEPENDENCE	57	119
SEALAND INNOVATOR	69	51
SEALAND INTEGRITY	116	104
SEALAND KODIAK		4
SEALAND LIBERATOR	75	121
SEALAND MARINER	40	
SEALAND NAVIGATOR	197	239
SEALAND PACIFIC	181	213
SEALAND PATRIOT	43	102
SEALAND PERFORMANCE	65	93
SEALAND PRODUCER	96	250
SEALAND QUALITY	68	92
SEALAND RELIANCE	117	207
SEALAND SPIRIT	77	155
SEALAND TACOMA	57	168
SEALAND TRADER	186	129
SEALAND VALUE	76	58
SEALAND VOYAGER	85	141
SEALIFT MEDITERRANEAN,		65
SEAWARD JOHNSON	112	33
SEDCO/BP 471	101	261
SEMINOLE		48
SENATOR	110	25
SGT. METEJ KOCAK	1	38
SHELDON LYKES	62	135
SHELLY BAY	39	130
SHENAHON	29	32
SHIRAOI MARU	169	66
SIDNEY STAR	198	
SINCERE GEMINI	28	143
SINCERE SUCCESS	39	
SKANDERBORG	27	
SKAUBRYN	109	
SKAUGRAN	145	156
SKAUKAR	71	30
SKODSBORG	32	43
SOLAR WING	68	56
SONORA	58	
SOUTHLAND STAR	169	
SPRING BEAR	49	
ST BLAIZE	69	
ST. CLAIR	97	118
STAFFORDSHIRE	167	
STAR ALABAMA	23	48
STAR AMERICA	32	70
STAR DRIVANGER	74	
STAR DROTTANGER	91	
STAR EAGLE	112	130
STAR EVVIVA	30	7
STAR FLORIDA	104	153
STAR FRASER	72	
STAR FUJI	58	
STAR GEIRANGER	18	42
STAR GEORGIA	2	
STAR GRAN	56	44
STAR GRINDANGER	18	
STAR SKOGANGER,NORWAY	8	36
STAR WESTCHESTER	68	
STAR WILMINGTON	4	
STATE OF MAINE	13	
STELLA LYKES	26	
STENA TRANSFER	195	232
STEWART J. CORT	442	478
STOLT HAWK	22	
STONEWALL JACKSON	23	24
STRIDER ISIS	38	26
STRIDER JUNO	6	
STRONG ICELANDER	49	119
STRONG VIRGINIAN	15	
SUE LYKES	56	
SUGAR ISLANDER	21	
SUN SWAN	24	
SUNBELT DIXIE	103	48
SUNRISE RUBY	95	74
SYNNOVE KNUSTEN	52	39
T.S.EMPIRE STATE	30	51
TABASCO	60	
TAI CHUNG	170	172
TAI HE	36	
TAI SHAN		51
TAI SHING	15	38
TAMPA	10	
TAMPA BAY	76	84
TARKWA	11	
TEXAS CLIPPER	25	
TEXAS SUN	13	19
TEXAS TRADER	20	42
THOMAS G. THOMPSON	145	185
THOMPSON LYKES	40	47
THOMPSON PASS	2	56
TILLIE LYKES	51	128
TOKYO HIGHWAY	34	
TOLUCA	266	255
TONCI TOPIC	5	
TONSINA	38	76
TORM FREYA	76	36
TORRENS	27	
TOWER BRIDGE	75	
TRANSWORLD BRIDGE	133	63
TRICORD SUCCESS	54	212
TRIGGER	145	92
TRITON	259	294
TROPIC ISLE		9
TROPIC LURE		22
TROPIC OPAL		9
TROPIC QUEST		85
TROPIC TIDE	1	
TROPICAL BEAUTY		112
TROPICALE	16	5
TSL BOLD	300	502
TULSIDAS	10	
TYSON LYKES	40	116
UCHOA	159	215
ULLSWATER	225	
ULTRAMAX	30	
ULTRASEA	13	32
UNIVERSE	24	
USCGC ACACIA (WLB406)	11	5
USCGC ACUSHNET WMEC 16	26	
USCGC BASSWOOD (WLB 38	9	
USCGC BEAR (WEMC 901)	25	
USCGC BOUTWELL WHEC 71	25	
USCGC BRAMBLE (WLB 392	4	
USCGC CAMPBELL	94	
USCGC CHASE (WHEC 718)	51	
USCGC CITRUS (WMEC 300	130	8
USCGC COURAGEOUS	19	
USCGC DEPENDABLE	65	
USCGC DILIGENCE WMEC 6	1	4
USCGC DURABLE (WMEC 62	42	
USCGC EAGLE (WIX 327)	40	
USCGC ESCANABA	13	
USCGC ESCAPE (WMEC 6)	17	
USCGC FIREBUSH WLB 393	7	
USCGC FORWARD	136	50
USCGC GALLATIN	20	
USCGC GALVESTON ISLAND	7	
USCGC HAMILTON WHEC 71	53	61
USCGC HARRIET LANE	53	
USCGC IRONWOOD (WLB 29	29	
USCGC JARVIS (WHEC 725	135	
USCGC MACKINAW	8	8
USCGC MADRONA	4	
USCGC MALLOW (WLB 396)	12	
USCGC MELLON (WHEC 717	59	79
USCGC MIDGETT (WHEC 72	69	
USCGC MOHAWK WMEC 913	72	
USCGC MORGENTHAU	1	
USCGC MUNRO	84	
USCGC NORTHLAND WMEC 9	81	84
USCGC POLAR SEA__(WAGB	103	
USCGC POLAR STAR (WAGB	78	92
USCGC RELIANCE WMEC 61	48	
USCGC RESOLUTE WMEC 62	53	
USCGC RUSH	142	94
USCGC SASSAFRAS	14	
USCGC SEDGE (WLB 402)	38	
USCGC SENECA	60	83
USCGC SPENCER	67	186
USCGC STORIS (WMEC 38)	125	
USCGC SUNDEW (WLB 404)	16	
USCGC SWEETBRIER WLB 4	16	
USCGC TAHOMA	22	
USCGC TAMAROA (WMEC 16	47	
USCGC TAMPA WMEC 902	31	33
USCGC VIGILANT WMEC 61	4	
USCGC YOCONA (WMEC 168	15	52
USNS ABLE	18	
USNS ALGOL	6	
USNS ANTARES		85
USNS APACHE (T-ATF 172	29	
USNS BARTLETT(T-AGOR 1	89	
USNS BELLATRIX	44	44
USNS CAPELLA	10	19
USNS CATAWBA T-ATF 168	16	19
USNS CONCORD		31
USNS GUS W. DARNELL	78	27
USNS KANAWHA T-AO 196		44
USNS LITTLEHALES (T-AG	40	232
USNS MAURY	4	
USNS MOHAWK (T-ATF 170	42	45
USNS NARRAGANSETT	126	
USNS NAVAJO_(TATF-169)	47	
USNS PECOS	24	
USNS POWHATAN TATF 166	85	
USNS PREVAIL	13	
USNS RANGE SENTINEL_T-		3
USNS REGULUS	8	
USNS SEALIFT ANTARCTIC		101
USNS SEALIFT ARABIAN S	46	
USNS SEALIFT ARCTIC	80	
USNS SEALIFT ATLANTIC	93	134
USNS SEALIFT CHINA SEA	25	11
USNS SEALIFT MEDITERRA	123	46
USNS SEALIFT PACIFIC	2	20
USNS SILAS BENT T-AGS	18	
USNS SIOUX	24	111
USNS VANGUARD TAG 194	80	
USNS VICTORIOUS	65	
USNS WALTER S. DIEHL	4	51
USNS WILKES T-AGS-33	52	24
VAN TRADER	25	62
VERA ACORDE	25	77
VINE	186	
VIRGINIA	103	323
VIVA	59	177
WASHINGTON RAINBOW #2	73	107
WECOMA	152	156
WELLINGTON STAR	178	
WEST MOOR	196	
WESTERN FUTURE	15	
WESTWARD	54	98
WESTWARD VENTURE	107	135
WESTWOOD ANETTE	75	70
WESTWOOD BELINDA	31	
WESTWOOD CLEO	108	87
WESTWOOD JAGO	127	98
WESTWOOD MARIANNE	39	165
WILFRED SYKES	181	203
WILLIAM E. MUSSMAN	3	41
WOLVERINE	52	32
WORLD WING #2	68	44
YANKEE CLIPPER	34	
YOUNG SATO	29	12
YOUNG SPROUT	75	80
ZETLAND	207	
ZIM AMERICA	41	
ZIM CANADA	84	
ZIM HOUSTON	19	
ZIM IBERIA	34	
ZIM KEELUNG	101	
ZIM MARSEILLES	11	
ZIM MIAMI	48	
ZIM SAVANNAH	49	

SUMMARY: GRAND TOTAL VIA RADIO 65717

GRAND TOTAL VIA MAIL 54501

TOTAL UNIQUE OBS 89831

TOTAL DUPLICATES 30387 (33.8%)

UNIQUE RADIO OBS.35330 (39.3%)

UNIQUE MAIL OBS. 24114 (26.8%)

Bathy–Tesac Data at NMC

April, May, and June 1993

CALL SIGN	TOTAL	BATHY	TESAC	SHIP NAME
BOAB	6	6	0	TAI HE
CBVM	11	11	0	VINA DEL MAR
CGBS	144	0	144	PARIZEAU
CGDG	27	0	27	HUDSON
CG2676	6	6	0	SHAMOOK
CG2958	94	0	94	TULLY
CG2965	7	7	0	W.E. RICKER
CZDO	40	40	0	QUEST
C6JY6	117	117	0	MELBOURNE STAR
C6JZ2	94	94	0	AMERICA STAR
DAKE	128	128	0	KOELN ATLANTIC
DBKV	55	55	0	SEETEUFEL
DD8436	37	37	0	FEHMARNBELT
DGLM	104	104	0	MONTE ROSA
DGVK	106	106	0	COLUMBUS VICTORIA
DGZV	57	57	0	COLUMBUS VIRGINIA
DHCW	86	86	0	COLUMBUS WELLINGTON
DIDA	22	22	0	ARIANA
DIXX	53	53	0	DAGMAR AENN
DLEZ	25	25	0	YANKEE CLIPPER
DREI	5	5	0	LINDAU
DREO	1	1	0	WILHELM
D5BC	37	37	0	SEDCO BP/471
D5ND	29	29	0	SAINT LUCIA
D5NE	105	105	0	MT CABRITE
D5NZ	66	66	0	POLYNESIA
ELAX2	7	7	0	MICRONESIAN PRIDE
ELBX3	23	23	0	PACKING
ELEH4	55	55	0	DELMAS TOURVILLE
ELHL6	78	78	0	COLUMBUS OHIO
ELIL9	100	100	0	T A NAVIGATOR
ELIS8	92	92	0	T A MARINER
ELOF6	27	27	0	LONGAVI
ELOF7	9	9	0	LOA
EREC	112	7	105	PRILIV
FHQB	18	18	0	ALIS
FNDK	58	58	0	PATRICIA DELMAS
FNGB	4	4	0	MARION DUFRESNE
FNGS	58	58	0	LA FAYETTE
FNJT	1	1	0	KORRIGAN
FNOM	12	12	0	RENOIR
FNQC	40	40	0	RENEE DELMAS
FNQM	62	62	0	SUZANNE DELMAS
FNWC	18	18	0	NATHALIE DELMAS
FNXN	15	15	0	SAINT ROMAIN
FNXW	18	18	0	SAINT ROCH
FNZO	92	92	0	RABELAIS
FNZP	37	37	0	RACINE
FNZQ	13	13	0	RIMBAUD
FPYO	1	1	0	CAP SAINT PAUL
FWQP	4	4	0	A. NIZERY
GACA	119	119	0	CUMULUS
GLNE	54	54	0	DISCOVERY
GQEK	45	45	0	FORTHBANK
GXRH	22	22	0	ENDURANCE
GYRW	40	40	0	ENCOUNTER BAY
GYSA	34	34	0	FLINDERS BAY
GYSE	33	33	0	NEDLLOYD TASMAN
HPAN	3	3	0	MICRONESIAN COM-
MERCE				
HPEW	106	106	0	PACIFIC ISLANDER
H9BQ	31	31	0	MICRONESIAN INDEPENDENCE
JBOA	71	71	0	KEIFU MARU
JCCX	71	71	0	CHOFU MARU
JDDS	90	90	0	***
JDSS	16	16	0	HAKUHO MARU
JDWX	125	125	0	KOFU MARU
JFDG	75	75	0	SHUMPU MARU
JFPQ	119	119	0	KASHIMASAN MARU
JGZK	135	135	0	RYOFU MARU
JITV	128	128	0	WELLINGTON MARU
JIVB	84	84	0	SEIFU MARU
JKCF	37	37	0	GEORGE WASHINGTON BR
JMSDF	62	62	0	CINCSDFLT JSMDF JA
JNZL	68	68	0	KAIYO MARU
JRBM	23	23	0	OGASAWARA MARU
JRPG	8	8	0	KAIYOU
JSVY	3	3	0	SHIRASE
J8GC9	45	45	0	FRONTIER
KGJB	21	21	0	SEALAND DEFENDER
KIRH	90	90	0	SEALAND TRADER
KNBD	1	1	0	DELAWARE II
KNFG	138	138	0	SEA WOLF
KRGB	110	110	0	SEALAND ENTERPRISE
KVWA	28	28	0	TEXAS CLIPPER
LADB2	36	36	0	SKAUGRAN
LAJV4	56	56	0	SKAUBRYN
LRGS	25	0	25	***
NASW	16	16	0	WADSWORTH
NAVOCE	133	133	0	U.S. NAVAL OCEANOGRAPHIC
NBTM	48	48	0	POLAR STAR
NCQI	1	1	0	AINSWORTH
NHTE	13	13	0	ELROD
NICB	1	1	0	***
NIDK	11	11	0	ICEPAT GROTON CT
NIKA	11	11	0	SEALIFT ATLANTIC
NNJB	3	3	0	***
NNUD	16	16	0	SILAS BENT
NRUO	46	46	0	POLAR SEA
NZSK	99	99	0	E.KANE
N900AM	160	160	0	***
OWUO6	109	109	0	MOANA PACIFIC
PGFE	4	4	0	NEDLLOYD VAN DIEMEN
PJJU	59	59	0	OLEANDER
RV1	145	145	0	***
RV2	96	96	0	***
RV3B	16	16	0	***
RV6	110	110	0	***
RV7	8	8	0	***
SA205	31	31	0	***
SCOU	1	1	0	TV 243
SEXN	1	1	0	TV 227
SEYD	1	1	0	TV 274
SHIP	978	978	0	***
SJIB	1	1	0	TV 282
SKVP	5	5	0	TV 284
SMZJ	2	2	0	TV 105
SMZQ	1	1	0	TV 102
S6FK	162	162	0	SWAN REEFER
TFEA	29	29	0	BJARNI SAEMUNDSSON
TFJA	4	4	0	ARNI FRIDRIKSSON
TFVD	16	16	0	***

April, May, and June 1993

CALL SIGN	TOTAL	BATHY	TESAC	SHIP NAME
TWR2	1	1	0	***
TWR3	3	3	0	***
UFJN	130	0	130	VILNYUS
UINF	17	16	1	VLADIMIR PARSHIN
UQHM	32	0	32	ABAKANLES
VC9450	9	0	9	GADUS ATLANTICA
VJBQ	32	32	0	ANRO AUSTRALIA
VJDI	42	42	0	IRON NEWCASTLE
VJDP	52	52	0	IRON PACIFIC
VKCN	15	15	0	CANBERRA
VKCV	37	37	0	DERWENT
VKLC	19	19	0	BRISBANE
VKLP	6	6	0	HMAS MELBOURNE
VKMK	71	71	0	SWAN
VKML	10	10	0	SYDNEY
VKPT	13	13	0	PERTH
VLNB	30	30	0	TORRENS
VSBI3	79	79	0	BIBI
VXN8	739	739	0	AIRCRAFT
WECB	6	6	0	MELVILLE
WPGK	78	78	0	SEALAND NAVIGATOR
WPKD	93	93	0	SEALAND ACHIEVER
WRBA	2	2	0	PACMISRAN HAWAII
WRBB	4	4	0	PACIFIC MISSLE RANGE
WSRL	99	99	0	SEALAND PACIFIC
WTDK	10	10	0	D.S. JORDAN
WTDM	14	0	14	MILLER FREEMAN
WTDO	125	122	3	OREGON II
WTED	16	16	0	CHAPMAN
WTER	13	4	9	MALCOLM BALDRIGE
WTES	45	44	1	SURVEYOR
WUS9293	1	1	0	MOANA WAVE
WXBR	21	21	0	CHEVRON MISSISSIPPI
XCSH	55	55	0	TABASCO
YDLR	62	62	0	BOGASARI LIMA
Y3CH	2	0	2	PROF. ALBRECHT PENK
ZCAQ9	267	266	1	WEST MOOR
ZCKP	15	15	0	STAR DRIVANGER
ZCKU	48	48	0	STAR DROTTANGER
ZDAZ6	93	93	0	T A EXPLORER
3EAW7	5	5	0	ANDINO
3EET4	24	24	0	SEAS EIFFEL
3EGR6	53	53	0	RECIFE
3EHT6	32	32	0	KARINA BONITA
7JOB	8	8	0	CALIFORNIA CERES
7KDD	71	71	0	YOKO MARU
9VBZ	14	14	0	MAHSURI
9VUU	23	23	0	ANRO ASIA
9VVB	88	88	0	GOLDENSARI INDAH
9VWM	12	12	0	NEW ZEALAND STAR
21002	548	548	0	BUOY
21004	717	717	0	BUOY
22001	722	722	0	BUOY
32315	93	93	0	BUOY
32316	93	93	0	BUOY
32317	94	94	0	BUOY
32318	90	90	0	BUOY
32319	88	88	0	BUOY
32320	94	94	0	BUOY
32321	95	95	0	BUOY
32322	96	96	0	BUOY
43001	97	97	0	BUOY
51006	91	91	0	BUOY
51007	101	101	0	BUOY
51008	58	58	0	BUOY
51009	91	91	0	BUOY
51010	88	88	0	BUOY
51011	48	48	0	BUOY
51014	86	86	0	BUOY
51015	80	80	0	BUOY
51016	49	49	0	BUOY
51017	67	67	0	BUOY
51018	90	90	0	BUOY
51019	91	91	0	BUOY
51020	93	93	0	BUOY
51021	94	94	0	BUOY
51022	260	260	0	BUOY
51023	95	95	0	BUOY
51301	269	269	0	BUOY
51302	95	95	0	BUOY
51303	90	90	0	BUOY
51304	93	93	0	BUOY
51305	93	93	0	BUOY
51306	96	96	0	BUOY
51307	48	48	0	BUOY
51308	90	90	0	BUOY
51309	95	95	0	BUOY
51310	92	92	0	BUOY
52001	93	93	0	BUOY
52002	90	90	0	BUOY
52003	92	92	0	BUOY
52004	88	88	0	BUOY
52006	92	92	0	BUOY
52007	87	87	0	BUOY
52008	86	86	0	BUOY
52010	20	20	0	BUOY
52011	88	88	0	BUOY
52012	86	86	0	BUOY
52301	11	11	0	BUOY
52302	61	61	0	BUOY
52303	32	32	0	BUOY
52304	48	48	0	BUOY
52305	39	39	0	BUOY
52306	53	53	0	BUOY
52307	79	79	0	BUOY
52309	85	85	0	BUOY
52310	85	85	0	BUOY
52311	87	87	0	BUOY
52312	85	85	0	BUOY
52313	87	87	0	BUOY
52314	45	45	0	BUOY

TOTAL BATHYS RECEIVED	16033
TOTAL TESACS RECEIVED	597
TOTAL REPORTS RECEIVED	16630

April, May and June 1993

Wave observations are taken each hour during a 20–minute averaging period, with a sample taken every 0.67 seconds. The significant wave height is defined as the average height of the highest one–third of the waves during the average period each hour. The maximum significant wave height is the highest of those values for that month. At most stations, air temperature, water temperature, wind speed and direction are sampled once per second during an 8.0–minute averaging period each hour (moored buoys) and a 2.0–minute averaging period for fixed stations (C–MAN). Contact NDBC Data Systems Division, Bldg 1100, SSC, Mississippi 39529 or phone (601) 688–2838 for more details.

BUOY	LAT	LONG	OBS	MEAN AIR TP (C)	MEAN SEA TP (C)	MEAN SIG WAVE HT (M)	MAX SIG WAVE HT (M)	MAX SIG WAVE HT (DA/HR)	SCALAR MEAN WIND SPEED (KNOTS)	PREV WIND (DIR)	MAX WIND (KTS)	MAX WIND (DA/HR)	MEAN PRESS (MB)
April													
32302	18.0S	085.1W	0712	22.5	23.0	2.2	3.7	05/04	11.6	SE	20.6	04/14	1014.2
41001	34.7N	072.7W	0717	17.4	19.8	2.6	6.3	07/19	16.8	N	31.9	07/01	1014.2
41002	32.3N	075.2W	0714	19.0	21.7	2.3	6.3	07/03	15.8	N	34.0	01/18	1014.9
41004	32.5N	079.1W	0713	17.0	17.9				12.6	SW	28.6	16/06	1016.1
41006	29.3N	077.4W	0719	20.6	22.4	1.9	4.0	29/04	13.4	SE	27.6	05/14	1015.6
41009	28.5N	080.2W	1439	20.6	22.1	1.1	2.7	29/04	13.7	SE	33.6	01/10	1015.6
41010	28.9N	078.5W	1433	21.1	23.0	1.7	4.0	29/00	13.2	SE	30.9	05/13	1016.0
41016	24.6N	076.5W	0718	23.3	24.7	0.5	1.6	24/23	11.9	NE	23.2	24/16	1015.1
42001	25.9N	089.7W	0719	22.1	22.5	1.3	3.2	15/08	13.0	SE	33.8	04/19	1014.5
42002	25.9N	093.6W	0721	21.6	21.9	1.4	3.8	04/18	13.3	SE	29.3	04/15	1014.0
42003	25.9N	085.9W	0720	22.4	25.9	1.3	3.2	10/08	15.1	E	34.2	05/01	1015.3
42007	30.1N	088.8W	0678	18.1	19.4				13.9	SE	31.5	08/21	1015.0
42019	27.9N	095.0W	0719	20.8	22.1	1.6	3.7	24/10	14.7	SE	33.0	08 12	1013.3
42020	27.0N	096.5W	0709	21.6	22.1	1.5	3.9	24/11	13.7	SE	37.3	08 10	1012.8
44004	38.5N	070.7W	0718	12.0	13.0	2.6	6.7	23/11	16.6	S	33.6	23 10	1013.7
44005	42.6N	068.6W	0718		4.4	2.1	5.2	02/00					1014.2
44007	43.5N	070.1W	0718	5.1	4.0	1.4	4.7	02 03	11.8	NE	33.6	02 01	1015.7
44008	40.5N	069.4W	0376	8.3	6.0	2.2	5.0	27/22	16.5	S	33.6	27/21	1014.9
44011	41.1N	066.6W	0585	7.0	4.8	2.4	6.6	23/20	13.2	SE	29.1	28/03	1014.4
44013	42.4N	070.8W	0714	6.3	4.2	1.1	3.7	02/02	12.9	NE	34.6	02 00	1014.7
44014	36.6N	074.8W	0721	8.8	7.4	1.5	5.0	06 23	12.0	S	28.0	06 22	1015.1
44025	40.3N	073.2W	0712	7.1	5.2	1.4	3.1	17/06	12.4	S	29.5	17 05	1014.3
45001	48.1N	087.8W	0406	1.5	1.3	0.8	3.0	16 15	12.0	NE	29.3	16 09	1015.5
45002	45.3N	086.4W	0539	2.7	2.1	0.9	2.9	15 16	12.8	NE	32.3	16 00	1013.2
45003	45.3N	082.7W	0012	3.1	2.1	0.2	0.2	30/13	5.3	W	8.7	30 23	1016.8
45004	47.5N	086.5W	0405	1.4	1.4	0.9	3.0	16 14	12.5	SE	28.4	16/07	1014.9
45006	47.3N	089.9W	0415	2.2	1.2	0.9	3.1	16 14	9.1	NE	21.1	16 07	1015.1
45007	42.8N	087.1W	0476	3.5	2.9	0.6	2.5	16 05	10.6	N	27.8	01 03	1014.8
45008	44.3N	082.4W	0097	4.6	1.6	0.5	1.5	28 13	7.9	S	17.8	28 11	1020.7
46001	56.3N	148.2W	0715	4.4	4.6	2.8	6.0	01 21	12.8	SE	33.0	30 23	1001.8
46002	42.5N	130.3W	0700	10.8	10.8	3.7	8.2	01 08	15.0	SW	31.7	01 05	1014.8
46006	40.9N	137.5W	0715	11.4	11.9	4.2	9.1	15 01	18.8	W	33.4	14/19	1014.9
46013	38.2N	123.3W	0720	12.1	12.1	3.0	5.9	01 19	13.2	NW	31.9	30 02	1018.7
46023	34.3N	120.7W	0721	12.6	12.2	3.2	5.7	26 22	18.6	NW	27.8	02 07	1016.1
46025	33.8N	119.1W	0719	15.3	15.8	1.5	2.7	06 02	7.6	NW	24.5	06 03	1014.5
46026	37.8N	122.7W	0715	12.0	12.1	2.2	4.6	01 22	12.7	NW	29.9	30 03	1019.3
46027	41.8N	124.4W	0655	10.9	11.6	2.7	5.6	01 16					1018.4
46028	35.8N	121.9W	0716	12.6					17.3	NW	30.5	30 01	1018.3
46030	40.4N	124.5W	0719	11.4	11.6	2.4	5.5	01 19	11.8	SE	26.4	16 18	1019.1
46035	57.0N	177.7W	0717	0.1	1.8	2.0	4.8	20 20	14.7	NE	28.4	20 12	1003.3
46041	47.4N	124.5W	0711	9.7	10.8	2.7	5.8	26 02	13.1	S	29.1	25 11	1014.6
46042	36.8N	122.4W	0719	12.5		2.8	5.8	16 08	13.4	NW	24.3	11 06	1019.5
46045	33.8N	118.5W	0712	15.5	16.0	1.1	2.0	05 05	6.2	SW	20.6	06 00	1013.9
46047	32.7N	119.6W	0720	14.4	15.1	3.1	5.9	02 11	20.8	NW	33.0	22 23	1015.7
46048	32.9N	117.9W	0717	16.1	17.2	1.5	2.7	16 18	7.7	W	21.8	05 10	1014.2
46050	44.6N	124.5W	0710	10.5	10.8	3.0	6.0	01 20	12.9	S	27.4	01 13	1017.1
46051	34.5N	120.7W	0704	12.2	11.3	3.0	5.4	02 07	15.7	N	24.7	22 20	1016.8
51001	23.4N	162.3W	0717	23.0	23.7	2.4	5.4	16 20	11.8	E	20.2	19 04	1020.2
51003	19.3N	160.8W	0719	24.2	25.0	2.4	3.7	03 23	12.0	E	20.6	20 04	1016.8
51004	17.4N	152.5W	0716	23.6	24.3	2.7	3.9	22 22	17.2	E	23.8	30 19	1016.0

BUOY	LAT	LONG	OBS	MEAN AIR TP (C)	MEAN SEA TP (C)	MEAN SIG WAVE HT (M)	MAX SIG WAVE HT (M)	MAX SIG WAVE HT (DA/HR)	SCALAR MEAN WIND SPEED (KNOTS)	PREV WIND (DIR)	MAX WIND (KTS)	MAX WIND (DA/HR)	MEAN PRESS (MB)
51026	21.4N	157.0W	0494	23.0	23.8	2.7	4.4	03/21	15.9	E	23.5	12/07	1018.5
52009	13.7N	144.7E	0433		26.2	1.6	2.4	09/01	13.5	E	19.6	20 05	1011.7
91222	18.1N	145.8E	0696	26.1					6.7	E	19.3	11/17	1013.7
91251	11.4N	162.4E	0701	26.7					17.8	E	27.4	17 09	1011.6
91328	8.6N	149.7E	0613	27.0					9.5	NE	19.1	21/14	1009.4
91338	5.3N	153.7E	0696	27.6					5.9	NE	20.1	27/06	1008.8
91343	7.6N	155.2E	0697	27.1					11.5	NE	22.5	08/01	1009.7
91352	6.2N	160.7E	0697	27.3					11.0	NE	21.3	12/11	1009.8
91355	5.4N	163.0E	0700	27.1					8.9	NE	22.7	24/17	1008.8
91377	6.1N	172.1E	0707	27.0									1009.0
ABAN6	44.3N	075.9W	0702	6.0	2.6				4.8	N	20.5	01 05	1015.2
ALSN6	40.5N	073.8W	0718	7.9		1.1	2.6	08/00	16.7	S	36.7	20 20	1014.9
BURL1	28.9N	089.4W	0717	18.4					13.7	SE	42.4	08 20	1016.2
BUSL1	27.9N	090.9W	0325	21.6	22.8				13.3	SE	25.5	29/06	1016.0
BUZM3	41.4N	071.0W	0718	6.7					17.0	N	42.3	27 04	1014.3
CARO3	43.3N	124.4W	0719	10.4					12.1	S	34.4	15 07	1017.0
CHLV2	36.9N	075.7W	0716	10.2		1.2	3.6	06 20	17.5	S	35.7	06 21	1015.2
CLKN7	34.6N	076.5W	0718	13.9					13.0	S	35.8	05 21	1015.7
CSBF1	29.7N	085.4W	0712	17.6					8.4	SE	23.4	09 20	1015.7
DBLN6	42.5N	079.4W	0718	6.8					10.5	SW	30.5	17 18	1014.4
DESW1	47.7N	124.5W	0720	9.4					14.9	SE	39.5	17 21	1014.5
DISW3	47.1N	090.7W	0698	2.1					11.7	NE	37.5	01 03	1016.2
DPIA1	30.3N	088.1W	0713	17.6	19.2				13.3	SE	47.5	09 00	1015.3
DRYF1	24.6N	082.9W	0714	22.2	22.9				11.9	E	34.6	16 02	1015.4
DSLN7	35.2N	075.3W	0714	12.8					19.2	N	43.3	06 14	1015.4
FBIS1	32.7N	079.9W	0717	15.9					9.7	SW	24.1	27 05	1015.8
FFIA2	57.3N	133.6W	0720	6.9					7.8	N	22.1	12/18	1009.8
FPSN7	33.5N	077.6W	0660	16.0	15.5				17.0	S	40.4	16/07	1015.8
FWYF1	25.6N	080.1W	0717	22.8	24.1				13.7	E	26.7	15 11	1015.8
GDIL1	29.3N	090.0W	0703	18.9	20.4				11.6	SE	31.5	08 20	1014.9
GLLN6	43.9N	076.5W	0715	4.7					12.2	N	28.2	18 02	1014.4
IOSN3	43.0N	070.6W	0716	5.7					14.4	NE	41.6	02/01	1014.8
LONF1	24.9N	080.9W	0712	22.9	24.4				12.7	E	24.0	05 09	1015.4
MDRM1	44.0N	068.1W	0718	3.9					15.7	NE	38.0	01 22	1015.2
MISM1	43.8N	068.9W	0716	4.0					16.9	NE	49.3	02 01	1015.2
MLRF1	25.0N	080.4W	0716	23.0	24.2				12.8	E	24.2	10 07	1014.9
NWPO3	44.6N	124.1W	0717	10.2					11.1	S	28.2	01 22	1016.9
PILM4	48.2N	088.4W	0648	0.8					10.5	NE	23.9	02 04	1016.6
PTAC1	39.0N	123.7W	0717	11.1					8.4	N	25.1	11 23	1020.1
PTAT2	27.8N	097.1W	0682	20.3	21.0				13.9	SE	32.5	08 12	1012.5
PTGC1	34.6N	120.7W	0619	12.1					18.5	N	31.9	01 21	1016.6
ROAM4	47.9N	089.3W	0363	2.3					13.1	NE	32.3	16 08	1015.3
SANF1	24.5N	081.9W	0717	22.8	23.9				13.4	E	31.0	16 05	1014.9
SAUF1	29.9N	081.3W	0710	17.9	18.6				10.8	NE	26.9	27 09	1016.1
SBIO1	41.6N	082.8W	0437	8.6					11.8	SW	35.1	16 01	1014.3
SGNW3	43.8N	087.7W	0715	4.2					14.0	N	43.7	01 06	1012.2
SISW1	48.3N	122.9W	0718	9.6					11.9	SE	32.6	25 11	1015.1
SMKF1	24.6N	081.1W	0717	23.1	24.4				14.4	E	26.1	15 07	1015.7
SPGF1	26.7N	079.0W	0717	22.3	24.9				8.5	NE	21.6	22 15	1017.0
SRST2	29.7N	094.1W	0714	18.1					12.3	S	30.3	14 18	1014.3
STDM4	47.2N	087.2W	0717	1.2					15.6	NE	38.1	16 09	1015.3
SUPN6	44.5N	075.8W	0715	5.8	2.8				8.7	N	24.9	23 00	1013.3
SVLS1	32.0N	080.7W	0714	15.9	17.1	0.8	2.1	16 07	13.6	SE	32.4	27 06	1015.7
THIN6	44.3N	076.0W	0716	5.9									
TTIW1	48.4N	124.7W	0717	9.0					13.8	E	36.5	25 20	1014.7
VENF1	27.1N	082.5W	0714	19.7	22.2				10.1	NW	25.3	02 20	1016.3
WPOW1	47.7N	122.4W	0716	9.6					8.4	S	24.0	26 08	1014.9
May													
32302	18.0S	085.1W	0740	21.1	22.2	2.6	5.0	19 23	14.1	E	24.3	22 19	1016.4
41001	34.7N	072.7W	0741	20.8	22.3	1.4	3.3	12 16	12.1	SW	24.1	20 04	1017.0
41002	32.3N	075.2W	0739	21.6	22.5	1.2	2.6	14 13	8.5	S	28.8	22 09	1017.2
41004	32.5N	079.1W	0262	22.2	22.1	0.9	1.1	10 21	8.6	SE	17.5	05 05	1020.4
41006	29.3N	077.4W	0744	22.9	24.1	1.2	2.7	01 02	10.0	E	20.2	14 20	1016.5
41009	28.5N	080.2W	1480	23.7	24.0	0.9	1.8	01 05	11.9	SE	21.4	13 04	1015.7

BUOY	LAT	LONG	OBS	MEAN AIR TP (C)	MEAN SEA TP (C)	MEAN SIG WAVE HT (M)	MAX SIG WAVE HT (M)	MAX SIG WAVE HT (DA/HR)	SCALAR MEAN WIND SPEED (KNOTS)	PREV WIND (DIR)	MAX WIND (KTS)	MAX WIND (DA/HR)	MEAN PRESS (MB)
41010	28.9N	078.5W	1486	23.4	24.2	1.2	2.2	01/00	10.1	E	17.9	14/19	1016.6
41015	35.4N	075.3W	0199	19.8	19.5	0.9	1.5	30/14	9.4	SW	20.4	30/04	1019.2
41016	24.6N	076.5W	0741	24.6	25.3	0.6	1.6	31/23	12.4	E	21.0	23/17	1014.9
41017	35.4N	075.1W	0217	19.8	19.9	0.8	1.4	30/14	9.9	SW	19.4	30/07	1019.2
42001	25.9N	089.7W	0740	25.1	25.8	0.9	2.6	02/21	11.0	E	36.1	02/20	1013.7
42002	25.9N	093.6W	0742	24.2	24.2	1.1	2.6	02/23	10.9	SE	27.0	02/16	1013.4
42003	25.9N	085.9W	0744	24.7	25.9	0.9	2.7	03/12	12.0	E	27.2	03/04	1013.6
42007	30.1N	088.8W	0740	22.9	24.2				10.9	SE	29.3	02/06	1014.4
42019	27.9N	095.0W	0733	24.6	24.5	1.2	3.1	06/03	11.7	SE	30.3	06/02	1012.7
42020	27.0N	096.5W	0739	24.1	24.6	1.1	3.0	06/02	11.8	SE	28.0	05/22	1012.4
42035	29.2N	094.4W	0630	23.4	24.0	0.8	2.2	23/06	11.5	SE	25.6	24/15	1013.6
44004	38.5N	070.7W	0742	17.1	17.6	1.4	3.3	01/02	12.0	SW	23.3	12/03	1015.3
44005	42.6N	068.6W	0742		7.0	1.2	2.8	30/02					1013.4
44007	43.5N	070.1W	0741	10.4	8.7	0.8	2.4	01/03	9.3	S	25.6	29/18	1014.3
44008	40.5N	069.4W	0742	10.1	7.4	1.2	2.9	01/01	10.8	W	22.2	12/00	1014.4
44009	38.5N	074.7W	0345	15.6	14.9	0.6	1.3	25/02	9.4	S	22.9	18/18	1014.3
44011	41.1N	066.6W	0742	9.1	7.2	1.5	2.7	01/16	9.4	W	19.2	23/20	1014.2
44013	42.4N	070.8W	0743	12.7	10.4	0.5	1.6	01/00	10.3	W	27.2	29/20	1014.1
44014	36.6N	074.8W	0741	15.2	14.4	0.9	2.2	01/01	8.2	S	22.0	13/20	1016.7
44025	40.3N	073.2W	0711	13.2	11.5	0.9	1.8	25/11	9.3	S	20.8	29/14	1015.1
45001	48.1N	087.8W	0741	3.7	2.1	0.5	2.3	28/02	9.2	W	24.9	24/11	1015.1
45002	45.3N	086.4W	0740	5.2	2.9	0.4	1.5	14/16	7.7	S	20.0	31/01	1014.5
45003	45.3N	082.7W	0742	4.5	2.5	0.5	1.7	25/14	9.1	W	22.0	25/12	1014.5
45004	47.5N	086.5W	0742	3.7	2.2	0.5	2.2	25/02	9.4	NW	25.5	27/23	1014.7
45005	41.7N	082.4W	0454	12.2	10.9	0.5	1.3	12/23	8.9	SW	21.2	25/03	1012.9
45006	47.3N	089.9W	0741	4.3	2.1	0.6	2.2	24/10	7.3	NE	21.0	24/07	1014.7
45007	42.8N	087.1W	0742	6.6	4.1	0.5	3.5	13/01	8.1	SE	28.8	12/21	1014.5
45008	44.3N	082.4W	0121	6.1	1.9	0.4	0.8	03/20	8.0	SE	13.4	04/17	1019.2
46001	56.3N	148.2W	0740	6.2	6.3	2.0	6.6	01/01	10.0	S	29.7	01/01	1010.2
46002	42.5N	130.3W	0738	11.8	11.7	2.7	7.6	03/19	13.2	S	29.1	03/18	1011.4
46006	40.9N	137.5W	0737	11.5	12.2	2.8	7.7	03/13	14.9	W	33.2	03/02	1012.4
46013	38.2N	123.3W	0738	12.8	12.2	2.2	5.4	04/17	12.9	NW	31.7	01/01	1014.1
46014	39.2N	124.0W	0219	14.3	14.0	1.6	2.7	22/21	13.4	SE	24.7	26/03	1012.6
46022	40.8N	124.5W	0216	14.3	13.9	1.6	2.7	29/23	11.8	S	28.8	29/23	1011.6
46023	34.3N	120.7W	0738	13.7	13.3	2.1	5.0	05/01	12.1	NW	27.8	08/12	1014.3
46025	33.8N	119.1W	0739	16.2	17.6	1.3	2.8	08/04	7.7	W	21.8	08/03	1013.7
46026	37.8N	122.7W	0738	12.9	12.5	1.6	3.9	04/17	12.5	S	29.0	07/01	1015.0
46027	41.8N	124.4W	0006	11.2	10.7	2.4	2.8	01/01					1022.4
46028	35.8N	121.9W	0684	13.3					12.8	NW	29.7	08/13	1015.0
46030	40.4N	124.5W	0742	12.5	12.0	1.9	5.2	04/07	13.4	SE	27.6	14/04	1014.0
46035	57.0N	177.7W	0741	2.5	3.0	1.6	3.6	10/08	11.8	N	22.9	10/21	1009.9
46041	47.4N	124.5W	0732	12.5	13.6	1.8	3.9	04/16	9.8	S	27.4	21/02	1013.1
46042	36.8N	122.4W	0738	13.0		2.0	4.7	04/18	11.3	NW	25.6	07/08	1015.5
46045	33.8N	118.5W	0732	16.4	17.1	0.9	2.1	04/09	6.8	W	20.0	13/02	1013.1
46047	32.7N	119.6W	0742	15.4	16.0	2.1	5.9	08/05	14.7	NW	39.6	08/08	1014.7
46048	32.9N	117.9W	0744	16.8	18.1	1.3	2.6	08/09	9.3	W	23.1	19/00	1013.4
46050	44.6N	124.5W	0731	12.4	12.5	2.0	5.2	04/10	9.4	S	28.0	03/08	1014.5
46051	34.5N	120.7W	0741	13.5	13.1	1.8	4.8	05/00	11.1	NW	26.4	07/21	1015.2
51001	23.4N	162.3W	0742	23.5	24.7	2.0	3.9	05/20	12.4	E	24.4	02/08	1019.3
51003	19.3N	160.8W	0744	24.6	25.6	2.0	3.4	06/04	11.8	E	21.1	06/18	1015.9
51004	17.4N	152.5W	0738	23.8	24.8	2.1	3.4	01/12	13.8	E	24.4	03/03	1015.3
52009	13.7N	144.7E	0417		26.1	1.3	2.4	12/21	11.6	E	18.7	12/21	1010.9
91222	18.1N	145.8E	0731	27.2					6.6	E	15.7	04/03	1012.7
91251	11.4N	162.4E	0721	27.0					16.0	E	24.3	17/18	1011.3
91328	8.6N	149.7E	0739	27.7					7.6	NE	16.2	03/13	1009.6
91338	5.3N	153.7E	0695	27.6					5.0	NE	25.3	27/22	1009.0
91343	7.6N	155.2E	0736	27.4					8.9	NE	23.7	02/21	1010.0
91352	6.2N	160.7E	0737	27.3					8.9	NE	21.7	15/15	1009.9
91355	5.4N	163.0E	0732	26.9					6.3	E	23.2	08/14	1009.2
91377	6.1N	172.1E	0685	27.3					10.8	NE	24.8	30/15	1009.7
ABAN6	44.3N	075.9W	0741	12.2	7.9				3.6	S	17.3	03/11	1013.9
ALSN6	40.5N	073.8W	0742	14.8		0.7	1.6	01/04	13.1	S	32.4	11/22	1015.5
BURL1	28.9N	089.4W	0740	22.7					9.4	E	25.9	13/07	1014.6

BUOY	LAT	LONG	OBS	MEAN AIR TP (C)	MEAN SEA TP (C)	MEAN SIG WAVE HT (M)	MAX SIG WAVE HT (M)	MAX SIG WAVE HT (DA/HR)	SCALAR MEAN WIND SPEED (KNOTS)	PREV WIND (DIR)	MAX WIND (KTS)	MAX WIND (DA/HR)	MEAN PRESS (MB)
BUSL1	27.9N	090.9W	0741		24.4				9.8	E	26.7	01 14	
BUZM3	41.4N	071.0W	0743	12.2					12.9	SW	31.9	11 21	1014.3
CARO3	43.3N	124.4W	0741	12.6					9.6	S	34.0	24 00	1013.5
CHLV2	36.9N	075.7W	0742	17.2		0.7	1.5	01 05	12.5	S	27.1	15 23	1016.6
CLKN7	34.6N	076.5W	0741	20.2					9.3	SW	21.4	30 10	1017.4
CSBF1	29.7N	085.4W	0737	22.3					7.0	SE	19.1	14 01	1015.0
DBLN6	42.5N	079.4W	0741	12.4					10.4	SW	30.8	25 15	1015.3
DESW1	47.7N	124.5W	0742	12.5					11.5	S	34.9	07 16	1013.1
DISW3	47.1N	090.7W	0723	6.8					9.6	SW	48.7	24 06	1014.1
DPIA1	30.3N	088.1W	0740	22.7	24.3				10.2	SE	26.5	02 08	1014.5
DRYF1	24.6N	082.9W	0740	24.5	24.4				10.0	E	19.8	02 04	1014.4
DSLN7	35.2N	075.3W	0743	19.4					13.7	SW	29.5	12 05	1017.3
FBIS1	32.7N	079.9W	0743	22.1					7.9	SW	18.9	21 04	1016.6
FFIA2	57.3N	133.6W	0743	10.1					7.8	N	30.1	05 04	1012.3
FPSN7	33.5N	077.6W	0729	21.6	20.6				11.2	SW	26.8	22 03	1017.3
FWYF1	25.6N	080.1W	0740	25.0	25.6				14.4	E	25.3	23 03	1015.2
GDIL1	29.3N	090.0W	0737	23.4	25.6				9.1	E	25.4	02 00	1014.1
GLLN6	43.9N	076.5W	0741	8.8					11.8	SW	28.2	31 14	1014.5
IOSN3	43.0N	070.6W	0744	11.8					11.6	W	34.4	29 18	1013.8
LONF1	24.9N	080.9W	0743	25.1	26.4				12.3	E	23.6	31 23	1014.6
MDRM1	44.0N	068.1W	0740	7.5					11.3	S	27.0	29 21	1013.5
MISM1	43.8N	068.9W	0743	8.1					12.0	W	32.9	29 18	1013.7
MLRF1	25.0N	080.4W	0743	25.0	25.6				12.7	E	26.5	31 20	1014.2
WPO3	44.6N	124.1W	0741	12.5					8.2	S	30.1	21 01	1014.1
PILM4	48.2N	088.4W	0474	4.4					10.5	W	28.6	28 01	1013.5
PTAC1	39.0N	123.7W	0711	12.6					11.3	N	27.4	01 02	1015.0
ROAM4	47.9N	089.3W	0738	6.7					12.0	NE	36.2	27 21	1015.2
SANF1	24.5N	081.9W	0742	25.0	26.0				12.6	E	24.4	31 22	1014.0
SAUF1	29.9N	081.3W	0737	22.0	22.3				8.8	SE	20.6	05 03	1016.3
SBIO1	41.6N	082.8W	0742	14.2					10.3	E	28.0	24 20	1015.5
SGNW3	43.8N	087.7W	0740	9.5					10.0	S	34.7	13 00	1013.8
SISW1	48.3N	122.9W	0741	12.0					9.2	W	33.5	01 18	1013.3
SMKF1	24.6N	081.1W	0743	25.4	26.0				13.8	E	28.4	24 06	1014.8
SPGF1	26.7N	079.0W	0744	24.4	25.9				8.7	SE	20.1	23 14	1016.7
SRST2	29.7N	094.1W	0742	22.6					11.6	SE	36.4	24 03	1013.6
STDM4	47.2N	087.2W	0743	6.5					14.7	NW	34.8	12 01	1017.0
SUPN6	44.5N	075.8W	0743	12.1	8.7				8.5	SW	23.3	31 21	1013.4
SVLS1	32.0N	080.7W	0723	21.6	21.1	0.7	1.5	13 02	8.9	SE	24.4	13 05	1016.4
TTIW1	48.4N	124.7W	0742	12.0					11.7	S	30.9	13 00	1013.6
VENF1	27.1N	082.5W	0740	23.1	25.1				8.5	E	20.7	22 22	1015.5
WPOW1	47.7N	122.4W	0742	13.4					6.8	S	24.1	02 01	1012.5
June													
32302	18.0S	085.1W	0720	19.8	20.9	2.3	3.6	07 02	12.9	E	21.0	07 00	1016.6
41001	34.7N	072.7W	0720	23.0	23.4	1.2	2.2	06 18	10.0	SW	22.7	06 02	1018.0
41002	32.3N	075.2W	0718	24.0	24.4	1.1	2.5	02 20	8.9	S	18.3	05 02	1017.9
41006	29.3N	077.4W	0718	25.8	26.7	1.1	2.6	02 04	8.6	S	19.8	16 15	1017.5
41009	28.5N	080.2W	1438	26.2	26.6	0.7	1.7	17 19	9.2	SE	22.3	25 00	1017.0
41010	28.9N	078.5W	1439	26.2	26.9	1.1	2.1	03 00	9.2	S	22.0	28 20	1017.6
41015	35.4N	075.3W	0718	23.3	23.1	1.0	2.2	06 14	9.4	SW	28.4	05 02	1017.4
41016	24.6N	076.5W	0717	26.6	27.2	0.5	1.7	01 00	10.9	E	25.3	01 09	1016.6
41017	35.4N	075.1W	0719	23.4	23.4	1.0	2.2	06 11	10.0	SW	25.3	06 07	1017.3
42001	25.9N	089.7W	0718	27.7	28.1	0.9	2.7	19 08	13.0	SE	31.7	18 20	1015.1
42002	25.9N	093.6W	0710	27.1	27.1	1.3	5.1	19 06	14.2	SE	32.3	19 05	1013.7
42003	25.9N	085.9W	0718	27.5	27.9	0.8	2.5	18 20	9.8	E	20.8	18 19	1016.0
42007	30.1N	088.8W	0669	26.7	28.4				10.7	S	26.2	17 20	1016.2
42019	27.9N	095.0W	0719	28.0	27.1	1.4	4.3	19 15	12.8	SE	27.2	19 08	1013.4
42020	27.0N	096.5W	0718	26.9	27.2	1.3	4.6	19 14	13.7	SE	28.0	20 03	1012.6
42035	29.2N	094.4W	0716	27.1	27.7	1.1	3.8	19 21	13.3	SE	29.9	18 16	1014.2
44004	38.5N	070.7W	0719	19.9	19.6	1.1	2.7	23 14	9.5	SW	22.3	01 14	1016.7
44005	42.6N	068.6W	0719	13.5	10.9	1.1	3.1	07 06	9.8	SW	24.7	23 04	1014.0
44007	43.5N	070.1W	0718	14.2	11.4	0.6	2.7	01 14	9.7	SW	26.6	01 08	1014.0
44008	40.5N	069.4W	0720	14.1	10.8	0.9	2.2	28 07	10.6	SW	23.5	01 13	1015.8
44009	38.5N	074.7W	0718	19.5	18.7	0.7	1.4	01 05	6.7	N	11.3	30 05	1016.6
44011	41.1N	066.6W	0718	11.5	9.3	1.2	3.3	07 09	8.9	SW	23.1	01 20	1015.5

BUOY	LAT	LONG	OBS	MEAN AIR TP (C)	MEAN SEA TP (C)	MEAN SIG WAVE HT (M)	MAX SIG WAVE HT (M)	MAX SIG WAVE HT (DA/HR)	SCALAR MEAN WIND SPEED (KNOTS)	PREV WIND (DIR)	MAX WIND (KTS)	MAX WIND (DA/HR)	MEAN PRESS (MB)
44013	42.4N	070.8W	0717	16.5	13.1	0.4	1.6	01/11	11.1	SW	26.8	01/07	1014.4
44014	36.6N	074.8W	0720	21.0	20.5	0.8	2.0	01/15	8.7	S	23.1	06/08	1017.4
44025	40.3N	073.2W	0672	18.8	17.4	0.8	2.2	01/05	9.6	S	22.0	01/13	1015.8
45001	48.1N	087.8W	0718	5.4	3.1	0.5	1.5	24/18	8.5	SE	21.2	08/10	1014.9
45002	45.3N	086.4W	0718	8.4	5.7	0.4	1.6	26/20	7.3	S	23.3	26/19	1014.7
45003	45.3N	082.7W	0720	6.8	3.7	0.4	1.6	01/06	7.5	NW	21.4	01/04	1015.1
45004	47.5N	086.5W	0717	5.3	3.1	0.4	1.6	15/09	7.9	SE	20.8	15/08	1014.9
45005	41.7N	082.4W	0716	17.7	17.0	0.4	1.2	01/08	9.0	SW	22.3	01/06	1015.7
45006	47.3N	089.9W	0718	6.1	3.1	0.5	1.4	26/07	7.6	NE	17.2	24/19	1014.0
45007	42.8N	087.1W	0719	11.5	9.1	0.4	2.0	30/12	7.8	S	31.9	30/11	1014.6
45008	44.3N	082.4W	0518	11.2	7.9	0.4	1.2	16/01	6.9	N	16.3	09/23	1015.7
45010	43.1N	087.8W	0096	16.0	14.4	0.6	1.8	30/12	10.2	NE	29.0	30/09	1014.7
46001	56.3N	148.2W	0717	8.9	9.1	1.6	5.8	06/07	10.1	SE	26.4	05/16	1013.1
46002	42.5N	130.3W	0712	13.1	13.7	1.8	3.7	05/08	12.5	NW	24.7	05/07	1020.0
46006	40.9N	137.5W	0714	13.3	13.5	1.7	3.3	08/19	11.1	NW	24.7	08/18	1023.0
46013	38.2N	123.3W	0716	12.6	11.2	2.2	3.7	27/04	18.6	NW	31.3	16/09	1013.1
46014	39.2N	124.0W	0709	12.9	11.8	2.0	3.6	30/05	15.6	NW	28.4	30/02	1015.0
46022	40.8N	124.5W	0711	13.6	13.6	1.8	3.9	17/02	11.3	N	24.1	19/12	1016.9
46023	34.3N	120.7W	0720	14.1	13.9	2.3	4.1	11/19	14.5	NW	27.4	22/20	1012.0
46025	33.8N	119.1W	0718	17.6	19.3	1.1	2.3	06/01	6.5	W	25.1	06/01	1011.3
46026	37.8N	122.7W	0712	12.8	12.6	1.6	2.6	11/12	15.0	NW	28.0	11/11	1013.7
46028	35.8N	121.9W	0113	12.9	15.0	2.7	3.6	30/05	17.4	NW	26.8	30/04	1010.4
46029	46.2N	124.2W	0337	14.6	14.8	1.4	2.1	23/00	10.2	NW	19.9	20/01	1019.0
46030	40.4N	124.5W	0718	12.5	11.5	1.6	3.0	17/00	12.4	N	22.5	04/06	1016.5
46035	57.0N	177.7W	0688	5.8	5.8	1.3	4.7	27/08	11.9	SE	30.7	25/02	1013.4
46041	47.4N	124.5W	0698	13.7	14.9	1.4	3.1	07/21	9.2	NW	25.3	09/10	1017.1
46042	36.8N	122.4W	0715	13.4		2.1	3.4	11/15	14.4	NW	25.3	23/22	1014.3
46045	33.8N	118.5W	0708	17.9	18.9	0.7	1.7	06/05	5.9	SW	15.5	05/23	1010.9
46047	32.7N	119.6W	0719	16.3	17.2	2.1	4.7	11/14	14.5	NW	32.6	11/09	1012.2
46048	32.9N	117.9W	0719	18.3	19.8	1.1	1.9	11/18	7.1	W	19.0	05/16	1011.1
46050	44.6N	124.5W	0702	14.1	14.6	1.5	3.2	09/15	11.2	N	27.0	09/16	1018.5
46051	34.5N	120.7W	0718	13.7	13.4	2.0	3.7	23/07	13.0	NW	26.0	22/06	1013.1
51001	23.4N	162.3W	0001	25.3	26.2				13.7	E	13.7	01/03	1018.0
51002	17.2N	157.8W	0335	25.6	26.0	1.9	2.9	19/04	13.8	E	21.5	24/19	1015.0
51003	19.3N	160.8W	0524	25.5	26.3	1.6	2.9	03/23	11.2	E	20.3	03/16	1014.9
51004	17.4N	152.5W	0712	24.7	25.8	2.0	3.2	06/06	15.2	E	23.0	03/13	1014.5
51026	21.4N	157.0W	0159	24.5	25.1	1.6	2.3	26/18	15.3	E	22.7	25/08	1016.6
52009	13.7N	144.7E	0504		27.2	1.0	1.8	21/17	10.6	E	18.8	21/16	1010.6
91222	18.1N	145.8E	0711	28.4					5.3	E	13.2	29/02	1011.9
91251	11.4N	162.4E	0707	27.7					14.3	E	24.5	26/12	1011.1
91328	8.6N	149.7E	0711	27.8					6.9	NE	18.6	19/05	1009.6
91338	5.3N	153.7E	0710	27.3					4.5	NE	18.4	13/13	1009.2
91343	7.6N	155.2E	0716	27.6					8.6	NE	21.8	17/22	1009.5
91352	6.2N	160.7E	0712	27.5					7.6	NE	23.0	07/11	1009.9
91355	5.4N	163.0E	0708	26.8					5.9	E	21.4	25/15	1009.0
91377	6.1N	172.1E	0717	27.8					9.2	NE	25.6	26/06	1009.8
ABAN6	44.3N	075.9W	0719	16.4	13.2				2.8	S	10.1	05/22	1014.4
ALSN6	40.5N	073.8W	0719	18.9		0.7	1.9	01/03	13.5	S	31.7	23/02	1016.3
BURL1	28.9N	089.4W	0713	26.9					9.8	SE	30.2	15/03	1016.4
BUSL1	27.9N	090.9W	0704		27.4								
CARO3	43.3N	124.4W	0710	13.4					9.0	N	27.2	09/18	1017.5
CHLV2	36.9N	075.7W	0718	21.8		0.7	1.6	14/08	11.8	S	26.7	05/11	1017.4
CLKN7	34.6N	076.5W	0718	24.2					9.9	SW	24.6	01/23	1018.0
CSBF1	29.7N	085.4W	0713	26.4					6.7	W	21.4	30/17	1016.6
DBLN6	42.5N	079.4W	0718	17.7					9.6	SW	30.6	05/20	1015.9
DESW1	47.7N	124.5W	0714	13.4					9.9	NW	33.4	09/14	1017.1
DISW3	47.1N	090.7W	0718	10.7					10.3	NE	28.3	26/06	1013.4
DPIA1	30.3N	088.1W	0715	26.8	28.4				9.4	SW	25.8	01/07	1016.3
DRYF1	24.6N	082.9W	0719	27.5	27.7				8.5	E	26.4	25/05	1016.2
DSLN7	35.2N	075.3W	0716	23.7					13.1	SW	46.1	05/02	1017.9
FBIS1	32.7N	079.9W	0717	25.8					9.4	SW	24.3	02/02	1017.3
FFIA2	57.3N	133.6W	0720	12.6					6.3	S	19.4	09/15	1014.0
FPSN7	33.5N	077.6W	0717	24.9	25.4				11.8	SW	26.5	06/05	1017.9

NDBC Station Data Summary

BUOY	LAT	LONG	OBS	MEAN AIR TP (C)	MEAN SEA TP (C)	MEAN SIG WAVE HT (M)	MAX SIG WAVE HT (M)	MAX SIG WAVE HT (DA/HR)	SCALAR MEAN WIND SPEED (KNOTS)	PREV WIND (DIR)	MAX WIND (KTS)	MAX WIND (DA HR)	MEAN PRESS (MB)
FWYF1	25.6N	080.1W	0717	27.6	28.0				10.8	E	24.7	01/02	1017.0
GDIL1	29.3N	090.0W	0713	27.3	29.4				9.3	SE	42.7	15/00	1015.9
GLLN6	43.9N	076.5W	0719	14.5					11.5	SW	27.9	01/15	1014.8
IOSN3	43.0N	070.6W	0718	16.2					13.3	S	36.4	01/08	1013.6
LONF1	24.9N	080.9W	0718	27.7	29.7				9.9	E	23.2	01/02	1016.4
MDRM1	44.0N	068.1W	0719	10.7					13.1	SW	33.0	06/21	1013.1
MISM1	43.8N	068.9W	0718	11.7					14.1	SW	35.2	01/13	1013.3
MLRF1	25.0N	080.4W	0716	27.4	28.0				9.8	E	26.4	26/04	1016.0
NWPO3	44.6N	124.1W	0713	13.4					8.7	N	28.7	09/18	1018.0
PILM4	48.2N	088.4W	0716	7.9					11.0	W	26.1	26/21	1015.0
PTAC1	39.0N	123.7W	0711	12.4					12.6	N	25.7	23/23	1015.2
ROAM4	47.9N	089.3W	0718	10.2					12.1	NE	31.5	21/23	1014.5
SANF1	24.5N	081.9W	0720	27.5	28.5				10.2	SE	24.6	01/03	1015.8
SAUF1	29.9N	081.3W	0719	25.3	26.6				9.0	SE	19.0	04/00	1017.3
SBIO1	41.6N	082.8W	0720	19.0					10.0	SW	30.0	01/07	1016.3
SGNW3	43.8N	087.7W	0717	14.2					9.9	S	37.4	09/03	1014.0
SISW1	48.3N	122.9W	0719	12.6					11.5	W	29.0	07/03	1016.5
SMKF1	24.6N	081.1W	0719	28.0	28.6				10.5	E	29.0	26/03	1016.7
SPGF1	26.7N	079.0W	0717	26.8	28.3				5.6	SE	23.5	27/22	1018.3
SRST2	29.7N	094.1W	0715	26.9					13.2	S	30.4	19/20	1014.7
STDM4	47.2N	087.2W	0718	10.3					14.6	S	35.7	15/00	1011.4
SUPN6	44.5N	075.8W	0718	16.4	13.9				7.7	SW	24.8	01/16	1014.0
SVLS1	32.0N	080.7W	0720	25.4		0.7	1.6	02/20	10.9	SE	27.8	28/23	1017.1
TTIW1	48.4N	124.7W	0718	12.8					9.2	W	32.7	09/20	1017.4
VENF1	27.1N	082.5W	0713	26.0	28.9				7.3	E	22.1	14/23	1017.1
WPOW1	47.7N	122.4W	0716	14.0					4.7	S	25.0	09/22	1015.8

Port Meteorological Services

DMA Representatives

Tom Hunter
DMA/HTC Rep.
ATTN: MCC 3
(Mail Stop D44)
4600 Sangamore Rd.,
Bethesda, MD 20816
301-227-3370

Walt Holgren
DMA/HTC Gulf Coast Rep.
One Canal Place
365 Canal St., suite 2300
New Orleans, LA. 70130
504-589-2642

Gary Rogan
DMA/HTC West Coast Rep.
2518 B Custom House
300 South Ferry St.
Terminal Island, CA 90731
310-514-6177

SEAS Field Representatives

Mr. Robert Decker
Seas Logistics/ PMC
7600 Sand Point Way N.E.
Seattle, WA 98115
206-526-4280
FAX: 206-526-6365
TELEX 7408535/BOBD UC

Mr. Steven Cook
SEAS Operations Manager
8604 La Jolla Shores Dr.
La Jolla, CA 92037
619-546-7103
FAX: 619-546-7003
TELEX 7408528/ COOK UC

Mr. Jim Farrington
SEAS Logistics/ A.M.C.
439 West York St.
Norfolk, VA 23510
804-441-3062
FAX: 804-441-6495
TELEX7408830/ MAPA UC

Mr. Robert Benway
National Marine Fisheries Service
28 Tarzwell Dr.
Narragansett, RI 02882
401-782-3295
FAX: 401-782-3201

Mr. Warren Krug
Atlantic Oceanographic & Met. Lab.
4301 Rickenbacker Causeway
Miami, FL 33149
305-361-4433
FAX: 305-361-4582
TELEX 7408765 LORI UC

Steve Ranne, Petty Officer USN
FLENUMOCEANCEN, Code 64
Monterey, CA 93943
408-647-4428
FAX: 408-647-4489

Northwest England
Captain Albert Britain, PMO
Room 218,
Royal Liver Building
Liverpool L3 1HU
Tel: 051-236 6565 FAX: 051-227 4762

Scotland and Northern Ireland
Captain Stuart M. Norwell, PMO
Navy Buildings, Eldon St.
Greenock, Strathclyde PA16 7SL
Tel: (0475) 24700 FAX: (0475) 892879

Bristol Channel
Captain Archie F. Ashton, PMO
Cardiff Weather Centre
Southgate House, Wood Street
Cardiff CF1 1EW
Tel: Cardiff(0222) 221423
FAX: (0222) 390435

Southwest England
Captain Douglas R. McWhan, PMO
8 Viceroy House
Mountbatten Centre
Millbrook Rd. East
Southampton SO1 OHY
Tel: Southampton (0703) 220632
FAX: (0703) 337341

Southeast England
Captain Clive R. Downes, PMO
Daneholes House, Hogg Lane
Grays, Essex RM17 5QH
Tel: Grays Thurrock (0375) 378369
FAX: (0375) 379320

Northeast England
Captain John Steel, PMO
Room D418 Corporation House
73-75 Albert Road
Middlesbrough, Cleveland TS1 2RZ
Tel: Middlesbrough (0642) 231622
FAX: (0642) 242676

East England
Captain Edward J. O'Sullivan, PMO
Customs Bldg, Albert Dock
Hull HU1 2DP
Tel: Hull (0482) 20158
FAX: (0482) 28957

New Zealand
Julie Fletcher, PMO
Met. Service of New Zealand Ltd.
Tahi Rd., PO Box 1515
Paraparaumu Beach, New Zealand
Tel: 64 4 2973237 FAX: 64 4 2973568

Japan
S. Sasanara, PMO
Yokohama Local Met. Observatory
Yamate-cho, Naka-ku
Yokohama, Japan
Tel: (045)-621-1991

M. Miyauchi
Japan Meteorological Agency
Otemachi, Chiyoda-ku
Tokyo, 100 Japan
Tel: (03)-212-8341

Hong Kong
Sui Fui Ip, PMO
Royal Observatory Ocean Centre Office
Room 1454, Ocean Centre
5 Canton Road, Hong Kong
Tel: 852 732-9263 FAX 852 375-7555

Germany
Henning Hesse, PMO
Wetterwarte, An der neuen Schleuse
Bremerhaven Tel: (0471) 72220

Jurgen Guhne, PMO
Deutscher Wetterdienst,Seewetteramt
Bernhard Nocht-Strasse 76
20359 Hamburg
Tel: (040) 3190 8826

Kenya
Ali J. Mafimbo, PMO
PO Box 98512
Mombassa
Tel: (11) 25685 or 433440

Saudi Arabia
Mahmud Rajkhan, PMO
Met. and Envir. Protection Admin.
PO Box 1358 Jeddah
Tel: (020) 683-4444 ext. 325

Singapore
Edmund LEE Mun San, PMO
Meteorological Service, PO Box 8
Singapore Changi Airport
Singapore 9181
Tel: 5457198

France
Yann Prigent, PMO
Station Mét., Noveau Semaphore
Quai des Abeilles, Le Harve
Tel: 35.42.21.06

P. Coulon
Station Météorologique
de Marseille-Port
12 rue Sainte Cassien,13002 Marseille
Tel: 91.91.46.51, poste 336

South Africa
C. Sydney Marais, PMO
Roggebaai, Capetown, 8012
Tel: (021) 217543

Peter Rae, PMO
Meteorological Office
Louis Botha Airport, Durban 4029

Australia
M. Hills, PMA
Pier 14, Victoria Dock
Melbourne, Vic.
Tel: (03) 629 1810

Captain Alan H. Pickles, PMA
Stirling Marine, 17 Mews Road
Fremantle, WA 6160
Tel: (09) 335 8444 Fax: (09) 335 3286.
Telex: 92821

E.E. Rowlands, PMA
NSW Regional Office
Bureau of Meteorology
580 George St., Sydney, NSW 2000
Tel: (02) 269 8555 FAX: (02) 269-8589

Greece
George E. Kassimidis, PMO
Port Office, Piraeus
Tel: (00301) 4135502
(00301) 9628942

China
YU Zhaoguo
Shanghai Meteorological Bureau
166 Puxi Road
Shanghai, China

Keyna
Ali Juma Mafimbo
PMO, Mombassa
Port Meteorological Office
P.O. Box 98512
Mombasa, Keyna

Malaysia
NG Kim Lai
Assistant Meteorological Officer
Malaysian Meteorological Service
Jalan Sultan, 46667 Petaling
Selangor, Malaysia

Mauritius
Goonasilan Soopramania
Principal Meteorological Tech.
Meteorological Services
St. Paul Road
Vacoas, Mauritius

Poland
Jozef Kowalewski
PMO, Gdynia and Gdansk
Inst. of Meteorology and Water Mgmt.
Marine Branch
81-342 Gdynia ul. Waszingtonia 42

Norway
Tor Inge Mathisen, PMO
DNMI-Vervarslonga På Vestlandet
Allègt 70
5007 Bergen, Norway

Sweden
Morgan Zinderland
SMHI
S-601 76 Norrköping, Sweden

Denmark
PMO
Danish Meteorological Instit.
Lynbyvej 100
Copenhagen, Ø, Denmark

Atlantic Ports

Charles E. Henson, PMO
National Weather Service, NOAA
1600 Port Boulevard
Miami, FL 33132
305-358-6027 or 305-530-7850

Lawrence Cain, PMO
National Weather Service, NOAA
Jacksonville International Airport
Box 18367
Jacksonville, FL 32229
904-741-4370

Earle Ray Brown, Jr., PMO
National Weather Service, NOAA
Norfolk International Airport
Norfolk, VA 23518
804-441-6326 FAX: 804-441-6495

James Saunders, PMO
National Weather Service, NOAA
Weather Service Office
BWI Airport
Baltimore, MD 21240
410-850-0529 FAX: 410-859-5129

Martin Bonk, PMO
National Weather Service, NOAA
Building 51
Newark International Airport
Newark, NJ 07114
201-645-6188

Dan Pero, PMO
National Weather Service, NOAA
30 Rockefeller Plaza
New York, NY 10112
212-399-5569

Randy Sheppard, PMO
Atmospheric Environment Service
1496 Bedford Highway
Bedford, (Halifax) Nova Scotia B4A
1ES 902-426-6703

Denis Blanchard
Atmospheric Environment Service
100 Alexis Nihon Blvd., 3rd Floor
Ville St. Laurent, (Montreal) Quebec
H4M 2N6
514-283-6325

D. Miller, PMO
Atmospheric Environment Service
Bldg. 303, Pleasantville
P.O. Box 21130, Postal Station "B"
St. John's, Newfoundland A1A 5B2
709-772-4798

Gulf of Mexico Ports

John Warrelmann, PMO
National Weather Service, NOAA
Int'l Airport, Moisant Field, Box 20026
New Orleans, LA 70141
504-589-4839

James Nelson, PMO
National Weather Service, NOAA
Houston Area Weather Office
1620 Gill Road
Dickinson, TX 77539
713-534-2640

Pacific Ports

PMO, W/PRx2
Pacific Region, NWS, NOAA
Prince Kuhio Fed. Bldg., Rm 411
P.O. Box 50027
Honolulu, HI 96850
808-541-1670

Robert Webster, PMO
National Weather Service, NOAA
501 West Ocean Blvd.
Room 4480
Long Beach, CA 90802-4213
310-980-4090 FAX: 310-980-4089
TELEX: 7402731/BOBW UC

Robert Novak, PMO
National Weather Service, NOAA
1301 Clay St.
Oakland, CA 94612-5217
510-637-2960 FAX 510-637-2961
TELEX: 7402795/WPMO UC

David Bakeman, PMO
National Weather Service, NOAA
7600 Sand Point Way, N.E.
BIN C15700
Seattle, WA 98115
206-526-6100

Bob McArter, PMO
Atmospheric Environment Service
700-1200 W. 73rd Av.
Vancouver, British Columbia
V69 6H9
604-664-9136

MIC
National Weather Service, NOAA
Box 37, USCG Base
Kodiak, AK 99619
907-487-2102/4338

Lynn Chrystal, OIC
National Weather Service, NOAA
Box 427
Valdez, AK 99686
907-835-4505

Marine Program Mgr. W/AR121x3
Alaska Region
National Weather Service
222 West 7th Avenue #23
Anchorage, AK 99513-7575
907-271-5121

Great Lakes Ports

Bob Collins, PMO
National Weather Service, NOAA
333 West University Dr.
Romeoville, IL 60441
815-834-0600 FAX: 815-834-0645

George Smith, PMO
National Weather Service, NOAA
Hopkins International Airport
Federal Facilities Bldg.
Cleveland, OH 44135
216-265-2374

Port Meteorological Officer
Atmospheric Environment Service
25 St. Clair Av. East
Toronto, Ontario
M4T 1M2
416-973-5809

Ronald Fordyce
National Water Research Institute
Port Meteorological Office
P.O. Box 5050
867 Lakeshore Rd.
Burlington, Ontario
L7R 4R6
905-312-0900 (FAX 905-312-0730)

U.S. Headquarters

Vincent Zegowitz
Marine Obs. Program Leader
National Weather Service, NOAA
1325 East West Highway
Silver Spring, MD 20910
301-713-1724

Martin Baron
VOS Program Manager
National Weather Service, NOAA
Room 17345
1325 East West Highway
Silver Spring, MD 20910
301-713-1724

Richard DeAngelis, Editor
Mariners Weather Log, NODC
1825 Connecticut Av., NW
Washington, DC 20235
202-606-4561
Fax: 202-606-4586

United Kingdom Headquarters

Captain Gordon V. Mackie,
Marine Superintendent, BD (OM)
Meteorological Office Met O (OM)
Scott Building, Eastern Road
Bracknell, Berks RG12 2PW
Tel:(0344) 855654 Fax: (0344)
855921
Telex: 849801 WEABKA G

Australia Headquarters

A.D. Baxter, Headquarters
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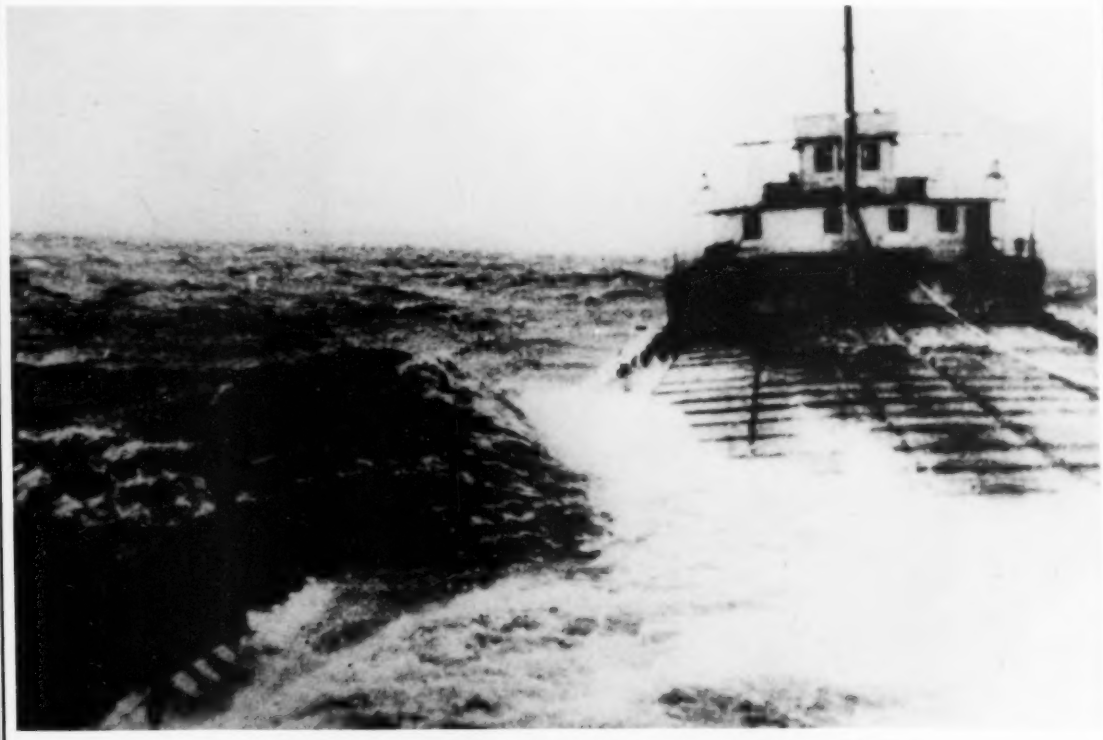

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